Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

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SESSION III, PART 1: KEEPING WATER FRESH:
THE VALUE OF IMPROVED FRESH WATER QUALITY

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DISCLAIMER

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Session III, Part 1: Keeping Water Fresh: The Value of Improved Fresh Water Quality

Recreation Demand Using Physical Measures of Water Quality[1]

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Abstract

This paper incorporates a rich set of physical water quality attributes, as well as site and household characteristics, into a model of recreational lake usage in Iowa. Our analysis shows individuals are responsive to physical water quality measures and WTP estimates are reported based on improvements in these measures.

1 Introduction

Over three decades have lapsed since the passage of the 1972 Clean Water Act (CWA), yet progress towards meeting the standards set forth in the CWA has been slow in the area of nonpoint source pollution. The most recent National Water Quality Inventory (USEPA,[17]) categorizes forty-five percent of assessed lake acres in the U.S. as impaired, with the leading causes of these impairments being nutrients and siltation. Moreover, few states have developed the priority ranking of their impaired waters or determined the Total Maximum Daily Loads (TMDLs) as required under Section 303(d) of the CWA.[1] Legal actions by citizen groups have prompted renewed efforts towards developing both the priority listing and associated TMDL standards.[2] However, the task facing both the EPA and state regulatory agencies remains a daunting one. The prioritization process alone, which is all the more important given current tight budgets, requires information on the cost of remediation and the potential benefits that will flow from water quality improvements. Both types of information are in short supply. The purpose of this paper is to help fill this gap by providing information on the recreational value of water quality improvements as a function of detailed physical attributes of the water bodies involved. The water quality values are obtained from a recreation demand model of lake usage in the state of Iowa, combining trip and socio-demographic data from the Iowa Lakes Valuation Project and an extensive list of physical water quality measures collected by Iowa State University's Limnology Lab.

Recreation demand models have long been used to value water quality improvements, but studies typically rely on limited measures of water quality. The most commonly used indicators are fish catch rates (e.g., [3], [11]). However, catch rates are themselves endoge-

[1] TMDL's specify the amount of a pollutant that a water body can receive and still meet existing water quality standards.

[2] As of March 2003, there have been approximately 40 legal actions taken against the USEPA in 38 states concerning the implementation of Section 303(d) of the CWA.

nous, depending on both fishing pressure and the abilities of the anglers, and provide only indirect measures of the underlying water quality. Physical water quality measures, such as secchi depth and bacteria counts, are used only sparingly, in large part due to limitations in available data. Phaneuf, Kling and Herriges [14] use fish toxin levels in their model of Great Lakes fishing, but the toxin levels were available only for a limited number of aggregate sites in the region. Parsons and Kealy [13] use dummy variables based on dissolved oxygen levels and average secchi depth readings to capture the impact of water quality on Wisconsin lake recreation. Similarly, Parsons, Helm, and Bondelid [12] construct dummy variables indicating *High* and *Medium* water quality levels for use in their analysis of recreational demand in six northeastern states. These dummy variables are based on pollution loading data and water quality models, rather than direct measurements of the local water quality. In all of these studies, the physical water quality indicators are found to significantly impact recreation demand, but, due to the limited nature of the measures themselves, provide only a partial picture of value associated with possible water quality improvements.

Bockstael, Hanemann, and Strand's [2] analysis of beach usage in the Boston-Cape Cod area has perhaps one of the most extensive lists of objective physical water quality attributes included in a model of recreation: oil, fecal coliform, temperature, chemical oxygen demand (COD), and turbidity. However, the study also points out one of the frequently encountered problems in isolating the impact of individual water quality attributes - multicollinearity. Seven additional water quality measures were available to the analysts: color, pH, alkalinity, phosphorous, nitrogen, ammonia, and fecal coliform. These latter variables were excluded from the analysis due to correlations among the various groups of water quality measures. The five water quality variables used were chosen because they were either directly observable by recreationists or highly publicized. While these choices are certainly reasonable given limitations in the available data, the lack of direct information on how nutrient levels (phosphorous and nitrogen) impact recreational usage is unfortunate in the context of setting TMDL standards in midwestern states, where nutrient loadings are of particular concern.

The contribution of the current paper lies in our ability to incorporate a rich set of physical water quality attributes, as well as site and household characteristics, into a model of recreational lake usage in Iowa. Trip data for the study are drawn from the 2002 Iowa Lakes Survey, the first of a four year project aimed at valuing recreational lake usage in Iowa. The survey was sent to a random sample of 8,000 Iowa households, eliciting information on their recreational visits to Iowa's 129 principle lakes, along with socio-demographic data and attitudes towards water quality issues. The unique feature of the project, however, is that a parallel inventory of the physical attributes of these lakes is being conducted by Iowa State University's Limnology laboratory.[3] Three times a year, over the course of a five year project, eleven distinct water quality measurements are being taken at each of the lakes, providing a clear physical characterization of the conditions in each lake. Moreover, due to the wide range of lake conditions in the state, Iowa is particularly well suited to identifying the impact of these physical characteristics on recreation demand. Iowa's lakes vary from a few clean lakes with up to fifteen feet of visibility to other lakes having some of the highest concentrations of nutrients in the world, and roughly half of the 129 lakes included in the study are on the EPA's list of impaired lakes.

The remainder of the paper is divided into five sections. Section 2 provides an overview of the two data sources. A repeated mixed logit model of recreational lake usage in Iowa is then specified in Section 3. The mixed logit model allows for a wide variety of substitution patterns among the recreational sites and for heterogeneity among households in terms of their reaction to individual site characteristics. (See, e.g., [7],[10], and [16]). Parameter estimates are reported in Section 4. In Section 5, we illustrate not only the implications of

[3] The limnological study is funded by the Iowa Department of Natural Resources.

the model in terms of recreational value of meeting the objectives of the CWA (i.e., removing all of the lakes in the state from the impaired water quality list), but also how the model can be used to prioritize the remediation task. Conclusions from the paper are provided in Section 6.

2 Data

Two principle data sources are used in developing our model of recreational lake usage in Iowa: the 2002 Iowa Lakes Survey and the physical water quality measures collected by Iowa State University's Limnology laboratory. As noted above, the 2002 Iowa Lakes Survey is the first survey in a four year study of lake usage in the state. The focus of the survey was on gathering baseline information on the visitation patterns to Iowa's 129 principle lakes, as well as socio-demographic data and attitudes towards water quality issues. After initial focus groups and pre-testing of the survey instrument, the final survey was administered by mail in November 2002 to 8,000 randomly selected households in the state. Standard Dillman procedures ([5]) were used to insure a high response rate.[4] Of the 8,000 surveys mailed, 4,423 were returned. Allowing for the 882 undeliverable surveys, this corresponds to an overall response rate of sixty-two percent.

The survey sample was initially paired down to 3,859 households as follows. Those individuals who returned the survey from out of state were excluded (thirty-eight observations). It is not feasible to ascertain whether these respondents have permanently left the state or simply reside elsewhere for part of the year. Respondents who did not complete the trip questions or did specify their numbers of trips (i.e. they simply checked that they had visited a given lake) were excluded (224 observations). Lastly, anyone reporting more than fifty-two total single day trips to the 129 lakes were excluded (133 observations). In the analysis

[4] Complete details of the survey design and implementation can be found in [1].

below, only single day trips are included to avoid the complexity of modeling multiple day visits. Defining the number of choice occasions as fifty-two allows for one trip per week to one of the 129 Iowa lakes. While the choice of fifty-two is arbitrary, it seems a reasonable cut-off for the total number of allowable single day trips for the season.[5] This last step eliminated approximately three percent of the returned surveys. Finally, due to the large number of respondents, the overall sample was randomly divided into three segments; specification, estimation, and prediction portions. The analysis reported here comes from the specification stage using 1,286 observations. Once the estimation stage is reached, the results will be free from any form of pretest bias and the standard errors will be not be biased by the extensive specification search.[6]

Table 1 provides summary statistics for trip and the socio-demographic data obtained from the survey. The average number of total single day trips for all 129 lakes is 6.68 varying from some respondents taking zero trips and others taking fifty-two trips. In general, the survey respondents are more likely to be older, male, have a higher income, and to be more educated than the general population. Schooling is entered as a dummy variable equaling one if the individual has attended or completed some level of post high school education.

The physical water quality measures used in modelling recreational lake usage in Iowa were gathered by Iowa State University's Limnology laboratory. Table 2 provides a listing of the water quality attributes and 2002 summary statistics for the 129 lakes used in our analysis. All of the physical water quality measures are the average values for the 2002 season. Samples were taken from each lake three times throughout the year, in Spring/early Summer, mid-Summer, and late Summer/Fall to include seasonal variation.

Each of the water quality measures help to characterize a distinct aspect of the lake

[5] Sensistivity analysis, raising the allowable number of trips per year above fifty-two, indicated that the results were not sensitive to the choice of this cut-off.

[6] Creel and Loomis [4] use a similar procedure in investigating alternative truncated count data estimators.

ecosystem. Secchi depth indicates the lake depth at which the bottom of the lake can still be seen, providing an overall water clarity measure. Chlorophyll is an indicator of plant biomass or algae, which in turn leads to greenness in the water. Three nitrogen levels are gathered. In addition to total nitrogen, NH3+NH4 measures particular types of nitrogen, such as ammonia, that can be toxic, whereas NO3+NO2 measures the nitrate level in the water. Total phosphorous is an important indicator of water quality in Iowa, as it is usually the principal limiting nutrient which determines algae growth. Silicon is important to diatoms, a key food source for marine organisms. The acidity of the water is measured by "pH" with levels below 6 or above 8 indicating unhealthy lakes. As Table 2 notes, all of the pH levels in this sample are tightly clustered between 7.3 and 10. Alkalinity is the concentration of calcium or calcium carbonate in the water. Plants need carbon to grow and all carbon comes from alkalinity, therefore alkalinity is an indication of the abundance of plant life. Inorganic suspended solids (ISS) consist basically of soil and silt in the water due to erosion, where as volatile suspended solids (VSS) consists of organic matter. Increases in either ISS or VSS levels will decrease water clarity. With the exception of pH levels, Table 2 demonstrates that there is considerable variation in water quality conditions throughout the state. For example, secchi depth varies from a low of 0.09 meters (or 3.5 inches) to a high of 5.67 meters (over 18 feet). Total phosphorus varies from 17 to 453 ug/L, some of the highest concentrations in the world.

In addition to trip and water quality data, two other data sources were used. First, the travel costs, from each survey respondent's residence to each of the 129 lakes, were needed. The out-of-pocket component of travel cost was computed as the roundtrip travel distance multiplied by $0.25 per mile.[7] The opportunity cost of time was calculated as one-third the estimated roundtrip travel time multiplied by the respondent's wage rate. Table 3 provides

[7] *PCMiler (Streets Version 17)* was used to compute both roundtrip travel distance and time.

summary statistics for the resulting travel cost variable. The average price of a recreational trip to a lake is \$136, although perhaps a more meaningful statistic is the average price of a lake visit, \$85.

Second, lake site characteristics were obtained from the Iowa Department of Natural Resources [9]. Table 3 provides a summary of these site characteristics. As Table 3 indicates, the size of the lakes varies considerably, from 10 acres to 19,000 acres. Four dummy variables are included to capture different amenities at each lake. The first is a "ramp" dummy variable which equals one if the lake has a cement boat ramp, as opposed to a gravel ramp or no boat ramp at all. The second is a "wake" dummy variable which equals one if wakes are allowed and zero otherwise. About 66% of the lakes allow wakes, whereas 34% of lakes are "no wake" lakes. The "state park" dummy variable equals one if the lake is located in a state park, which is the case for 38.8% of the lakes in our study. The last dummy variable is the "facilities" dummy variable. Facilities include things like restrooms, picnic tables, or vending machines. A concern may be that facilities would be strongly correlated with the state park dummy variable. However, while fifty of the lakes in the study are located in state parks and fifty have accessible facilities, only twenty six of these overlap.

3 The Model

The Mixed Logit model was chosen since it exhibits many desirable properties including, "it allows for corner solutions, integrates the site selection and participation decisions in a utility consistent framework, and controls for the count nature of recreation demand (Herriges and Phaneuf, [7])."

Assume the utility of individual i choosing site j on choice occasion t is of the form

$$U_{ijt} = V\left(X_{ij};\beta_i\right) + \varepsilon_{ijt},\ \ i = 1, ..., N;\ \ j = 0, .., J;\ \ t = 1, ..., T \tag{1}$$

where V represents the observable portion of utility, and from the perspective of the researcher, ε_{ijt}, represents the unobservable portion of utility. A mixed logit model is defined as the integration of the logit formula over the distribution of unobserved random parameters (Revelt and Train, 1998). If the random parameters, β_i, were known then the probability of observing individual i choosing alternative j on choice occasion t would follow the standard logit form

$$L_{ijt}\left(\beta_i\right) = \frac{\exp\left(V_{ijt}\left(\beta_i\right)\right)}{\sum\limits_{k=0}^{J} \exp\left[V_{ikt}\left(\beta_i\right)\right]}. \tag{2}$$

Since the β_i's are unknown, the corresponding unconditional probability, $P_{ijt}\left(\theta\right)$, is obtained by integrating over an assumed probability density function for the β_i's. The unconditional probability is now a function of θ, where θ represents the estimated moments of the random parameters. This repeated Mixed Logit model assumes the random parameters are $i.i.d.$ distributed over the individuals so that

$$P_{ijt} = \int L_{ijt}\left(\beta\right) f\left(\beta|\theta\right) d\beta. \tag{3}$$

No closed form solution exists for this unconditional probability and therefore simulation is required for the maximum likelihood estimates of θ.[8]

Following Herriges and Phaneuf [7], a dummy variable, D_j, is included which equals one for all of the one through J recreation alternatives and equals zero for the stay-at-home option ($j = 0$). Including the stay-at-home option allows a complete set of choices, including in the population those individuals who always "stay at home" on every choice occasion and do not visit any of the sites. It is convenient to partition the individual's utility into the stay-at-home option or choosing one of the J sites

$$U_{ijt} = \begin{matrix} \beta^{z'} z_i + \varepsilon_{i0t} \\ \beta_i' x_{ij} + \alpha_i + \varepsilon_{ijt}, \;\; j = 1, ..., J \end{matrix}, \tag{4}$$

[8] Randomly shifted and shuffled uniform draws are used in the simulation process (Hess, Train, and Polak, [8]). The number of draws used in the simulation is 750.

where α_i is the random parameter on the dummy variable, D_j, which does not appear since it equals one for $j = 1, ..., J$ and zero for $j = 0$. The vector z_i contains socio-demographic data such as income and age, and x_{ij} represents the site characteristics that vary across the lakes, including attributes such as facilities at the lake as well as water quality measures. Notice the parameters associated with the socio-demographic data are not random as this information does not vary across the sites.[9]

The random coefficient vectors for each individual, β_i and α_i, can be expressed as the sum of population means, b and a, and individual deviation from the means, δ_i and γ_i, which represents the individual's tastes relative to the average tastes in the population (Train, [16]). Therefore redefine

$$\beta_i' x_{ij} = b' x_{ij} + \delta_i' x_{ij} \tag{5}$$

$$a_i = a + \gamma_i \tag{6}$$

and then the partitioned utility is

$$U_{ijt} = \begin{matrix} \beta^{z'} z_i + \eta_{i0t} \\ \beta_i' x_{ij} + a + \eta_{ijt}, \;\; j = 1, ..., J \end{matrix}, \tag{7}$$

where

$$\eta_{ijt} = \begin{matrix} \varepsilon_{i0t} & & i = 1, ..., N; \;\; t = 1, ..., T \\ \delta_i' x_{ij} + \gamma_i + \varepsilon_{ijt}, & j = 1, ..., J; & i = 1, ..., N; \;\; t = 1, ..., T \end{matrix} \tag{8}$$

is the unobserved portion of utility. This unobserved portion is correlated over sites and trips due to the common influence of the terms δ_i' and γ_i which vary over individuals. For example, an individual who chooses the stay-at-home option for all choice occasions would have a negative deviation from a, the mean of α_i, while someone who takes many trips would have a positive deviation from a, allowing the marginal effect to vary across individuals. However, the parameters do not vary over sites or choice occasions; thus, the same preferences are used

[9] It is possible to interact the socio-demographic data with the sites, if one believed for example that income would effect which lake was chosen.

by the individual to evaluate each site at each time period. Since the unobserved portion of utility is correlated over sites and trips, the familiar IIA assumption does not apply for mixed logit models.

In particular, we model the utility individual i receives from choosing lake j on choice occasion t as

$$U_{ijt} = \begin{array}{l} \beta^{z'} z_i + \varepsilon_{i0t} \\ -\beta^P P_{ij} + \beta^{q'} Q_j + \beta_i^{a'} A_j + \alpha_i + \varepsilon_{ijt},\ j = 1, ..., J \end{array}, \tag{9}$$

where z_i is the socio-demographic data summarized in Table 1, P_{ij} is the travel cost from each Iowan's residency to each of the 129 lakes, as calculated with PCMiler (Table 3). The vector Q_j denotes the physical water quality measures (Table 2) and A_j represents the attributes of the lake (Table 3). As shown in equation (9), notice that the parameters on the lake attributes and the dummy variable, D_j, are random. These six variables are assumed to be independently normally distributed with the mean and dispersion of each variable estimated.

Finally, we estimate two models. The first specification, model A, includes six physical water quality measures. Included are the four paramount variables for nutrient criteria (USEPA [17]): total phosphorus, total nitrogen, chlorophyll, and Secchi depth, as well as inorganic suspended solids and organic suspended solids, which we consider to be crucial indicators as well. A second model, model B, includes the complete list of eleven water quality measures. Estimating two models allows us to observe the stability of the parameters across different specifications.

4 Results

The results for Model A and B are divided into two Tables, 4a and 4b. For both models, the coefficients for the socio-demographic data, price, and the random coefficients on the amenities are given in Table 4a. Table 4b lists for both models the coefficients for the physical water quality measures. All of the coefficients are significant at the 1% level except for a few of the socio-demographic data. For model B, with eleven physical water quality measures, only the "male" dummy variable is not significant. In Model A, income, household size, and the quadratic term on age are insignificant. Note that the socio-demographic data are included in the conditional indirect utility for the stay-at-home option. Therefore, the negative income coefficient indicates that as income rises the respondents are less likely to stay at home and more likely to visit a lake (i.e. lake visits are a normal good). Males, higher educated individuals, and larger households are all more likely to take a trip to a lake. Age has a convex relationship with the stay-at-home option and therefore a concave relationship with trips. For Model B, the peak occurs at about age 37, which is consistent with the estimate of larger households taking more trips, as at this age the household is more likely to include children.

The price coefficient is negative as expected and identical in both models. Now turning to the amenities parameters, again all of the parameters are of the expected sign. As the size of a lake increases, has a cement boat ramp, gains accessible facilities, or is in a state park, on average leads to increased trips. Notice however the large dispersion estimates. For example, in model A the dispersion on the size of the lake indicates 11.1% of the population prefers a smaller lake, possibly someone who enjoys a more private experience. The large dispersion on the "wake" dummy variable seems particularly appropriate given the potentially conflicting interests of anglers and recreational boaters. Anglers would possibly prefer "no wake" lakes and recreational boaters would obviously prefer lakes that allow wakes. It seems the population is almost evenly split with 56.9% preferring a lake that allows wakes and 43.1% preferring a "no wake" lake. Lastly, the mean of α_i, the trip dummy variable, is negative indicating that on average the respondents receive higher utility from the stay-at-home option, which is expected considering the average number of trips is 6.7 out of a possible 52 choice occasions.

The physical water quality coefficients are reported in Table 4b and are relatively stable across the two models. For both models A and B, secchi depth is positive and the suspended solids, both organic and inorganic (volatile), are negative, indicating the respondents strongly value water clarity. However, the coefficient on chlorophyll is positive suggesting on average respondents do not mind some variation of green water. The negative coefficient on total phosphorus, the most likely principal limiting nutrient, indicates higher algae growth leads to fewer recreational trips.

The only physical water quality coefficient to change qualitatively across the two specifications is total nitrogen which is positive in model A. Total nitrogen having a positive coefficient is consistent with expectations given the negative sign on total phosphorus. With such large amounts of phosphorus in the water, more nitrogen can actually be beneficial by allowing a more normal phosphorus to nitrogen ratio. If the ratio becomes too imbalanced more problematic blue-green algae blooms become dominant. Total nitrogen is negative in model B, but two other forms of nitrogen are included with the nitrates form (NO3+NO2) being positive, possibly for the same reason as just discussed.

Continuing with the additional measures in model B, alkalinity has a positive coefficient, consistent with alkalinity's ability to act as a buffering capacity on how much acidity the water can withstand before deteriorating. Since all of the lakes in the sample are acidic (i.e. pH greater than 7) a positive coefficient for alkalinity is expected. The positive coefficient on Silicon is also consistent since Silicon is important for diatoms, which in turn are an important food source for marine organisms. Lastly, pH is entered quadratically reflecting the fact that low or high pH levels are signs of poor water quality. However, as mentioned, in our sample of lakes all of the pH values are normal or high. The coefficients for pH show a convex relationship (the minimum is reached at a pH of 8.2) to trips, indicating that as the pH level rises above 8.2, trips are predicted to increase. This is opposite of what we expected and further specifications will consider this fact.

5 Welfare Calculations

Given the random parameters, β_i, the conditional compensating variation associated with a change in water quality from Q to Q' for individual i on choice occasion t is

$$CV_{it}(\beta_i) = \frac{-1}{\beta^p}\left\{\ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q';\beta_i\right]\right)\right] - \ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q;\beta_i\right]\right)\right]\right\}$$

which is the compensating variation for the standard logit model. The unconditional compensating variation does not have a closed form, but it can be simulated by

$$CV_{it} = \frac{1}{R}\sum_{r=1}^{R}\frac{-1}{\beta^p}\left\{\ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q';\beta_i^r\right]\right)\right] - \ln\left[\sum_{j=0}^{J}\exp\left(V_{ijt}\left[Q;\beta_i^r\right]\right)\right]\right\}$$

where R is the number of draws and r represents a particular draw from its distribution. The simulation process involves drawing values of β_i and then calculating the resulting compensating variation for each vector of draws, and finally averaging over the results for many draws. Following Von Haefen [18], 2,500 draws were used in the simulation.

Three water quality improvement scenarios are considered with the results from Model A used for all the scenarios. The first scenario improves all 129 lakes to the physical water quality of West Okoboji Lake, the cleanest lake in the state. Table 5 compares the physical water quality of West Okoboji Lake with the average of the other 128 lakes. All of West Okoboji Lake's measures are considerably improved over the other 128. For example, West Okoboji Lake has slightly over 5 times the water clarity, measured by secchi depth, of the other lakes. Given such a large change, the annual compensating variation estimates of $208.68 for every Iowa household seems reasonable (Table 7). Aggregating to the annual value for all Iowans simply involves multiplying by the number of households in Iowa which is 1,153,205.[10] Table 7 also reports the average predicted trips before and after the water

[10] Number of Iowa Households as reported by Survey Sampling, Inc., 2003.

quality improvement. Improving all 128 lakes to the physical water quality of West Okoboji Lake leads to a reasonable 14.1% increase in average trips. As expected, the predicted trips to West Okoboji Lake fall by 19.8% from 0.39 average trips per Iowa household to 0.31. Iowans can now choose the nearest lake with the attributes they prefer, instead of traveling further to West Okoboji Lake.

The next scenario is a less ambitious, more realistic plan of improving nine lakes to the water quality of West Okoboji Lake (see table 5 for comparison). The state is divided into nine zones with one lake in each zone, allowing every Iowan to be within a couple of hours of a lake with superior water quality. The nine lakes were chosen based on recommendations by the Iowa Department of Natural Resources for possible candidates of a clean-up project. The annual compensating variation estimate is $39.71 for each Iowa household. As expected, this estimate is 19.0% of the value if all lakes were improved, even though the scenario involves improving only 7.0% of the lakes. This suggests location of the improved lakes is important and to maximize Iowan's benefit from improving a few lakes, policymakers should consider dispersing them throughout the state.

The last scenario is also a policy oriented improvement. Currently of the 129 lakes, 65 are officially listed on the EPA's impaired waters list. TMDL's are being developed for these lakes and by 2009 the plans must be in place to improve the water quality at these lakes enough to remove them from the list. Therefore, in this scenario the 65 impaired lakes are improved to the median physical water quality levels of the 64 non-impaired lakes. Table 6 compares the median values for the non-impaired lakes to the averages of the impaired lakes. The table indicates the median values of the non-impaired lakes seems an appropriate choice with physical water quality measures higher than the averages of the 65 impaired lakes, but much below those of West Okoboji Lake. This scenario is valued considerably lower than the first two water quality improvement scenarios. The estimated compensating variation per Iowa household is $4.87. Consistent with this, the predicted trips only increase 0.3% over the predicted trips with no improvement in water quality. A reasonable conclusion is Iowan's have an abundance of lakes at this threshold level, and bringing the low quality lakes up to this level is not much of a benefit.

6 Conclusions

The first year survey of the Iowa Lakes Project gathered recreation behavior to 129 of Iowa's principal lakes. This data was combined with extensive physical water quality measures from the same set of lakes gathered by the Iowa State University Limnology Lab. Our analysis employing the repeated mixed logit framework, shows individuals are responsive to physical water quality measures and it is possible to base willingness to pay calculations on improvements in these physical measures. In particular we considered three improvement scenarios, with the results suggesting Iowans more highly value a few lakes with superior water quality rather than all recreational lakes at an adequate level, as determined by being listed as an impaired lake by the Environmental Protection Agency.

A number of important practical findings come directly from this work. Limnologists and other water quality researchers should be interested in the results of this paper, since the general belief is that visitors care about water clarity as measured by secchi depth (how many meters beneath the surface of the water a secchi dish is visible) or water quality in general. By estimating the partial effects of a list of physical measures, we have determined which significantly affect recreationist's behavior. Limnologists and water resource managers can then use this information about what physical lake attributes visitor's trip behavior responds to in designing projects for water quality improvements. Our results indicate water clarity is very important as evidenced by the secchi dish and suspended solids parameters. Also, nutrients in general are found to decrease recreation trips.

The findings from this study also have direct relevance for environmental protection managers and citizens concerned with the water quality in that they can be used to prioritize clean-up activities to generate the greatest recreation benefits for a given expenditure. Not only can the findings be used to determine which lakes and in what order to clean them, but also the most efficient levels of improvement.

Table 1. 2002 Iowa Lakes Survey Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Total Day Trips	6.68	10.46	0	52
Income	\$56,140	\$37,436	\$7,500	\$200,000
Male	0.67	0.46	0	1
Age	53.36	16.47	15	82
School	0.66	0.47	0	1
Household Size	2.61	1.32	1	12

Table 2. Water Quality Variables and 2002 Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Secchi Depth (m)	1.17	0.92	0.09	5.67
Chlorophyll (ug/l)	41	38	2	183
NH3+NH4 (ug/l)	292	159	72	955
NO3+NO2 (mg/l)	1.20	2.54	0.07	14.13
Total Nitrogen (mg/l)	2.20	2.52	0.55	13.37
Total Phosphorous (ug/l)	106	81	17	453
Silicon (mg/l)	4.56	3.24	0.95	16.31
pH	8.50	0.33	7.76	10.03
Alkalinity (mg/l)	142	41	74	286
Inorganic SS (mg/l)	9.4	17.9	0.6	177.6
Volatile SS (mg/l)	9.4	7.9	1.6	49.9

Table 3. Summary Statistics for Lake Site Characteristics

Variable	Mean	Std. Dev.	Min.	Max.
Travel Cost	135.79	29.47	94.12	239.30
Acres	672	2,120	10	19,000
Ramp	0.86	0.35	0	1
Wake	0.66	0.47	0	1
State Park	0.39	0.49	0	1
Facilities	0.39	0.49	0	1

Table 4a. Repeated Mixed Logit Model Parameter Estimates (Std. Errs in Parentheses)[a]

	Model A: 6 Water Quality Measures		Model B: 11 Water Quality Measures	
Variable	Mean	Dispersion	Mean	Dispersion
Income	-0.008^* (0.007)		-0.12^* (0.007)	
Male	-4.98^* (0.42)		-0.31 (0.42)	
Age	-0.24^* (0.07)		-0.58^* (0.08)	
Age^2	0.0001 (0.00006)		0.0078^* (0.0007)	
School	-4.45^* (0.40)		-3.44^* (0.40)	
Household	-0.41 (0.17)		-1.24^* (0.17)	
Price	-0.17^* (0.0006)		-0.17^* (0.0007)	
Log(Acres)	4.60^* (0.064)	3.81^* (0.057)	5.13^* (0.067)	4.05^* (0.06)
Ramp	11.60^* (0.78)	17.85^* (0.51)	14.87^* (0.89)	18.79^* (0.59)
Facilities	1.18^* (0.26)	18.09^* (0.28)	3.54^* (0.24)	16.78^* (0.25)
State Park	8.00^* (0.26)	15.15^* (0.27)	6.67^* (0.24)	13.99^* (0.27)
Wake	2.76^* (0.30)	15.81^* (0.33)	-1.64^* (0.30)	15.57^* (0.29)
α	-8.97^* (0.05)	3.01^* (0.04)	-9.19^* (0.05)	3.12^* (0.04)

* Significant at 1% level.

[a] All of the parameters are scaled by 10, except α (which is unscaled) and the income coefficient (which is scaled by 10,000).

Table 4b. Repeated Mixed Logit Model Parameter Estimates (Std. Errs in Parentheses)[a]

Variable	Model A: 6 Water Quality Measures	Model B: 11 Water Quality Measures
Secchi Depth (m)	0.78* (0.05)	0.84* (0.07)
Chlorophyll (ug/l)	0.054* (0.03)	0.06* (0.003)
NH3+NH4 (ug/l)		−0.002* (0.0006)
NO3+NO2 (mg/l)		3.16* (0.19)
Total Nitrogen (mg/l)	0.31* (0.01)	−3.21* (0.19)
Total Phosphorous (ug/l)	−0.0033* (0.001)	−0.016* (0.001)
Silicon (mg/l)		0.81* (0.02)
pH		−136.72* (5.83)
pH^2		8.35* (0.34)
Alkalinity (mg/l)		0.038* (0.002)
Inorganic SS (mg/l)	−0.010* (0.008)	−0.089* (0.009)
Volatile SS (mg/l)	−0.18* (0.01)	−0.28* (0.02)
LogLik	-47,740.38	-47,494.17

*Significant at 1% level.

[a] All of the parameters are scaled by 10.

Table 5. West Okoboji Lake vs. the other 128 Lakes

	West Okoboji Lake	Averages of the other 128 Lakes	Averages of the 9 Zone Lakes
Secchi Depth (m)	5.67	1.13	1.23
Chlorophyll (ug/l)	2.63	41.29	40.13
Total Nitrogen (mg/l)	0.86	2.22	3.64
Total Phosphorous (ug/l)	21.28	106.03	91.11
Inorganic SS (mg/l)	1.00	9.49	9.52
Volatile SS (mg/l)	1.79	9.43	8.42

Table 6. 64 Non-impaired Lakes vs. the 65 Impaired Lakes

	Median of the 64 Non-impaired Lakes	Averages of the 65 Impaired Lakes
Secchi Depth (m)	1.27	0.70
Chlorophyll (ug/l)	23.25	56.76
Total Nitrogen (mg/l)	1.11	2.77
Total Phosphorous (ug/l)	58.79	153.70
Inorganic SS (mg/l)	3.51	20.42
Volatile SS (mg/l)	6.02	15.49

Table 7. Annual Compensating Variation Estimates using Model A

Average CV	All 128 Lakes Improved to W. Okb.	9 Zone Lakes Improved to W. Okb.	65 Impaired Lakes Improved to Median
per choice occasion	\$4.01	\$0.76	\$0.09
per Iowa household	\$208.68	\$39.71	\$4.87
for all Iowa households	\$240,649,000	\$45,788,092	\$5,612,219
Predicted Trips (9.80 with current water quality)	11.18	10.06	9.83

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Choice Margins and the Measurement of Ecological Benefits:

The Case of Urban Watersheds

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Abstract

This paper outlines a new method for measuring the marginal willingness to pay for the services provided by ecological resources. The framework takes advantage of the choices consumers make for observable private goods affected by one or more of these services. Each of these decisions corresponds to a choice margin. The methodology uses the distinction between long and short run choices to integrate a hedonic property value model with recreation demand models differentiated by local housing neighborhoods. The demand models are used to develop a consistent quantity index for the contribution of the ecological services to the recreational activities that are expected to be possible in different residential locations. The hedonic model estimates the marginal value for small changes in this quality adjusted index for recreational opportunities. A new database on recreational activities linked with housing sales is used to evaluate the services provided by an urban watershed. The results support the proposed logic and indicate that marginal benefits of protecting watersheds, measured under the two different perspectives, are comparable, with the long run measure slightly larger than the benefits measured using ex post recreation choices.

Key Words: ecological services, marginal willingness to pay, joint hedonic and random utility models.

JEL Classification numbers: Q 26, Q 51, Q 57.

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I. Introduction

One of the most important challenges facing environmental policy analysts today stems from the need to measure the gains or losses arising from changes in the services of ecological resources.[1] In this paper we consider one aspect of these challenges – the task of measuring the welfare impacts of changes in water quality in a rapidly growing urban watershed. In many areas of this country increasing demands for residential housing and the subsequent development of supporting retail services have taxed the ability of watersheds to provide basic ecological services. At the same time, much of the growth in housing demand can be broadly viewed as amenity-driven. As a result, there is a fundamental tradeoff to be faced between the largely private benefits from increased development and the public costs of the amenity consequences stemming from development-related land cover changes. Designing effective public policy to address this tradeoff requires information of several types. Among these is an understanding of the economic benefits from enhancing the amenities provided by urban watershed services.

Three sources of benefit information are usually noted in providing responses to these needs: (a) contingent valuation (or conjoint) studies with hypothetical plans to improve (or avoid deterioration in) existing ecological resources such as wetlands (see Johnston et al. [1999], Bateman et al. [2004] and Woodward and Wui [2001] as examples); (b) hedonic property value models, using proxy measures, such as distance

[1] There are many potential examples supporting this judgment. The U.S. Environmental Protection Agency has recently established a federal advisory committee to consider the valuation of activities to protect ecological systems and services. Similar efforts are currently underway under the auspices of the National Academy of Sciences. Internationally the United Nations sponsored the Millennium Ecosystem Assessment which sought to evaluate how changes in ecosystems services affect human well being and the types of responses that can be adopted at local, national and global scales to improve ecosystem management.

between homes and the resource of interest to take account for the resource's effect on property values, (Leggett and Bockstael [2000], Mahan, Polaksy and Adams [2000]); and (c) travel cost recreation demand models estimating the value of amenity changes as they relate to the value of recreation visits (see Phaneuf [2002] and Egan, Herriges, Kling, and Downing [2004]). Applications using these approaches argue that they can address the general problem of valuing changes in ecosystem services, but their results remain somewhat disjointed. Each strategy exploits a different margin of choice and as a result appears to arise from a different model. Little guidance has been offered to explain the relationship between these methods' estimates of the values associated with enhanced ecosystem services.[2]

This paper proposes a framework to address these limitations by combining aspects of both the hedonic and recreation demand models. We develop a spatially varying, theoretically consistent index that summarizes the effects of watershed quality measures on the local recreation opportunities available because a household selects a residential neighborhood. We use a hedonic model to estimate the effect of both this index and the general amenity impacts on property values. Our strategy exploits the distinctive margins of choice associated with the different benefit measurement models. These choice margins relate to decisions with unique temporal dimensions. Short term, local recreation choices are used to develop indexes of how watershed quality affects the amount of recreation available. Asset values, the sales prices for private homes in our case, are determined by long term residential choices. They also depend on amenities.

[2] One of the reasons for this disparity stems from differences in the ways each method measures the environmental services linked to choices of private goods. Efforts to use joint estimation linking two or more methods have generally taken place where there is a well defined measure of these services (see Cameron [1992a] as an example).

To assure we can integrate the results from these two choices, we develop a framework that distinguishes the influence of amenities on expected local recreation from amenities as neighborhood attributes. Our choice margin approach exploits the logic of Pollak's [1969] conditional demand framework in describing the use of long and short run decisions to identify the value of water quality as it is reflected in both recreation opportunities and general amenity effects.

We evaluate our proposal using a new database gathered for Wake County, North Carolina. These data integrate property sales, recreation trips for a sample of over two thousand homeowners, and measures of the characteristics of the sub-hydrologic units comprising the county's watersheds. We estimate separate random utility models for local recreation trips for each of nineteen housing areas. Each model takes account of the travel time required for these short recreational outings and includes indexes of the watershed quality in the hydrological areas containing each recreation site. Our recreation quantity index is defined as the average of the conditional expected utility associated with the opportunities available in each housing area. By measuring the value of expected behavior arising from these short term trips (using the actual behavior of current residents) we have a consistent index of the importance of watershed quality for the outings available to each housing market area. Our framework provides a consistent bound for the marginal willingness to pay. It is estimated using the influence of this index on housing prices. We use a recent proposal to increase sewage capacity and permit growth in Granville County, which adjoins our study area, to illustrate how the framework can be applied. We treat the change as affecting the quality in a popular lake and assume for the calculations that it would lead to the loss of this recreational area for local outings.

The remainder of the paper is organized as follows. In the next two sections we discuss the conceptual basis for our approach and outline an operational model. This is followed by sections describing the Wake County database, our empirical specifications, and our estimates along with a policy application. The final section provides discussion of the general implications of our proposal.

II. Parsing Information from Different Choices

A. Conceptual Background

A choice margin describes an opportunity for an individual to make a decision that leads to the acquisition of both a private good *and* the services of a non-market good. These decisions can take place in both the long run and in day to day decisions, sometimes characterized as the short run. Long run choices involve the selection of neighborhoods and the purchase (or rental) of housing units. Short run decisions are conditional on these longer term selections and can involve trips to local recreation sites for short outings. Once a housing location choice is made, a household allocates remaining monetary and time resources to other purchased goods, leisure, and recreation. These decisions contribute to well-being in the short-run. As a result, it seems reasonable to expect that when deciding on a residential location the household considers the portfolio of amenities conveyed by the location, the accessibility of areas for recreation, and how these (or other) amenities relate to the quality of recreation opportunities. These factors will contribute to the expected future gains from recreation trips originating from the location.

To model these decisions formally we artificially divide the decision process into two steps, for each potential location and housing choice, a household is hypothesized to evaluate the short run decisions that could be made for recreation outings to maximize utility subject to its resource constraints at that location. Preferences are assumed to be a function of recreation trips, $x(q)$, a numeraire good z, and housing services $h(a,q)$ which at this stage are treated as quasi-fixed. The term a designates a vector of housing attributes including location specific characteristics. In equation (1) below we also include the term e to include unobserved heterogeneity in households that is not known by the analyst.

$$u = u(x(q), h(a,q), z, e) \tag{1}$$

$h(a,q)$ is treated as "given" from the perspective of the choices of $x(q)$ and z. This implies we can deduct its "cost" from income to derive the resources available for the short run budget constraint. That is, the income available for the next stage of the process – selecting $x(q)$ and z – is constrained by the remaining disposal income (i.e., $m = m^* - p_h(a,q)$ with m^* the full income and $p_h(a,q)$ the hedonic price function in annual terms).[3] The budget constraint for these short run decisions is given in equation (2).

$$m = m^* - p_h(a,q) = z + p_x \cdot x(q) \tag{2}$$

The first order conditions imply solutions for the recreation demands, other market goods, with the indirect utility function $V(p_x,m,q,e)$. This structure in turn implies that the

[3] We assume one unit of housing is consumed so $p_h(a,q)$ is the annual expenditure on housing.

realized ex post benefits for a given household from visits to recreation sites can be defined by equation (3).

$$MCS(q,e) = \int_{p_x}^{p_x^c} -\frac{V_{p_x}(\cdot\ ,q,e)}{V_y(\cdot\ ,q,e)} dp_x \qquad (3)$$

where p_x^c denotes the choke price for visits to the recreation site.

Using recreation demand models to estimate the benefits from an improvement in q requires describing how $MCS(q, e)$ changes with q. This analysis expands the integral given in (3) so that it considers changes in both p_x and q. We designated this expression as $\overline{MCS}(q^0, q^1)$.

This measure corresponds to the area between the two Marshallian demand curves at different values for q as defined in equation (4) below. The vertical line after the expression defined by Roy's identity, $(-V_{p_x}/V_m)$, designates that each Marshallian demand is evaluated at a different value for q. This expression is the type of analysis we discussed at the outset. It uses one type of choice margin, namely what is used to describe the consumption of recreation trips under different amenity conditions, to recover a measure of the value of the changes in amenity services from q_0 to q_1. To assure it is the full economic value for this change, conventional practice assumes x and q are weak complements. In addition, a symmetry condition, parallel to that imposed with multiple price changes, assures the consistency of line integrals. This logic follows from Palmquist [2004] and is one interpretation of the Willig [1978] condition usually cited as required for consistent measures of the consumer surplus arising from quality changes.

$$\overline{MCS}^A(q^o,q^1) = \int_{p_x^0}^{p_x^c(q^1)} \left(\left(-V_{p_x}/V_m\right)\Big|_{q^1} \right) dp_x - \int_{p_x^0}^{p_x^c(q^1)} \left(\left(-V_{p_x}/V_m\right)\Big|_{q^0} \right) dp_x \qquad (4)$$

To consider the potential for linkages between models associated with long and short run decisions, consider how the value of trips at a given quality level might influence other decisions. Equation (3) provides a summary of the gains due to the household's ability to take trips to the recreation site. It is the ex post benefit from the access conditions giving rise to recreation trips at a given quality level. In making a residential choice, it seems reasonable to suppose that households consider, ex ante, the expectation of what these benefits would be for each possible neighborhood. In other works, households consider the value of the recreation options implied by the choice of each neighborhood. Each area, in principle, provides somewhat different access conditions to recreation opportunities. As a result, we can argue that the expected benefits available from a residential location can be seen as an attribute of the location. With this simple model, we can define the expected benefits from recreation at a given residential location by

$$EMCS(q) = E[MCS(q,e)] \tag{5}$$

The expectation operator in this case is with respect to the heterogeneity across households in the location, both observed and unobserved. The latter is identified in our model by e. Equation (5) is not a household-specific measure. It is a measure of the average recreation opportunities available because a household has the access defined by one location compared to no access. Of course, in practice the choice is based on each neighborhood's relative value, so the default of no access becomes irrelevant. The expectation is across diverse households conditional on the level of q at each specific location. Using a long run perspective, we hypothesize that this value would be capitalized into housing prices in equilibrium.

To consider the long run version of our model we need to return to equation (1) and assume for each location a household has evaluated the potential for different patterns of local outings. This process implies that including $EMCS(q)$ in the preference function in equation (1) allows us to account for the sub-optimization that takes place conditional on a location. More formally, equation (6) offers a simple description for this objective function and (7) the relevant budget constraint

$$\max u(h(a,q), EMCS(q), z) \tag{6}$$

$$m^* = p_h(a,q) + p_x \cdot \tilde{x}(q, p_x, m(m^*)) + z \tag{7}$$

where $\tilde{x}(q, p_x)$ represents the optimized value of x (given the allocation of income relevant to choices of x with each housing location and $p_h(\,.\,)$). $m(m^*)$ acknowledges the separability in the decision process that we imposed on this problem -- recreation is based on the housing decision so the income remaining $m(m^*)$ is the connection associated with the budget decomposition in the choice process.

$p_h(a,q)$ is the hedonic price function. With x and z assumed to be selected as part of a separate decision process, optimal for each $h(a,q)$, we can recast the problem in equations (6) and (7) by holding $EMCS(q)$ constant for a location. Then the decision process involves selecting the location that is best, given the recreation and z choices that would be made for that location. The first order conditions in this case reflect the re-allocations in recreation use (captured through $\frac{\partial EMCS}{\partial q}$) and the changes in housing as in equation (8).

$$\frac{\frac{\partial u}{\partial EMCS}\cdot\frac{\partial EMCS}{\partial q}+\frac{\partial u}{\partial h}\cdot\frac{\partial h}{\partial q}}{\frac{\partial u}{\partial z}}=\frac{\partial p_h}{\partial q} \tag{8}$$

Households choose a residential location such that, at the margin, the value of expected recreation plus aesthetic benefits of the location are balanced against the implicit marginal purchase price of the amenities. Equation (8) implies that the elements of q can influence home prices both directly through the amenity effect and indirectly through the recreation effect.

Identifying these effects in hedonic models has proven challenging, and to our knowledge no studies have isolated both the direct and indirect effects shown in equation (8). Most hedonic studies rely on ad hoc proxy variables to control for the two effects. In the next sub-section we suggest how information from a recreation survey can be combined with housing sales information to operationalize our choice margin logic

B. Empirical Implementation

The approach outlined above, using the distinction between long run housing choices and short run recreation decisions, requires that we augment housing sales price information with recreation data. By matching the recreation usage of current residents to specific homes we can characterize both the relevant choice alternatives and the patterns of use. For example, suppose an urban watershed can be divided into J areas corresponding to well-defined real estate markets. The spatial layout of the landscape and existing amenity levels convey a similar portfolio of recreation opportunities (and qualities) to each resident in each of these market areas. Denote the set of recreation sites in each housing market area j by K_j and the amenities levels at these sites by q_j. Given observations on visits to sites by residents of zone j it is possible to estimate a random utility model of site choice. Denote the indirect utility for a visit by person i to site k by

$$u_{ik} = a + bt_{ik} + dq_k + e_{ik}, \quad k = 1,\ldots, K_j, \quad i = 1,\ldots, N_j \qquad (9)$$

where t_{ik} is a measure for the time cost for visiting site k, (a, b, d) denote parameters to be estimated, e_{ik} can be assumed to be a random error term distributed type I extreme value, and N_j is the number of person-trips observed in market area j. Given the error distribution, estimation of the parameters in (9) for observed trips originating from market area j is straightforward, and the expected maximum utility from the opportunities available for a trip originating in market area j is given in equation (10).

$$\hat{E}u_j(q) = N_j^{-1} \sum_{i=1}^{N_j} \ln\left[\sum_{k=1}^{K_j} \exp(\hat{v}_{ik})\right], \qquad (10)$$

where $\hat{v}_k$ is the predicted deterministic component of utility (i.e., $\hat{b}t_{ik} + \hat{d}q_k$, a cannot be identified, but does not affect the properties of the index).

The expected value of anticipated recreation derived from a location, as defined in equation (10), can also be interpreted as a "quantity index" for the set of recreation alternatives available in a given neighborhood. It is consistent with the outline we developed above. In this case, a linear expression for the outing choice model (i.e. equation (9)) allowed us to avoid considering the allocation of income to local outings.[4] We have also avoided assumptions about "pricing" the time (t_{ik}) required for these trips, because our objective is to measure an index for the recreational choice opportunities conveyed by each location. While we can use the model underlying (9) to measure the

[4] This assumption of locally constant marginal utility of income implies that the Marshallian measure of the value of trips and the Hicksian measure will be equal. Because our focus is on choices among locations for trips without a stay-at-home option, we do not consider selection effects arising from our survey response rate. This is an area for future research.

economic value of changes in the attributes of that choice set, our primary objective is to develop the quality adjusted quantity index.[5] A random utility framework assumes each trip decision is independent of every other such choice. Thus, under these conditions (and in the absence of income effects) equations (6) and (10) provide comparable measures for the effects of recreation for housing choices. The random utility approach has the added advantage of easily reflecting a wide array of site alternatives.

Thus, our index collapses a large amount of spatially explicit information on site availability and quality into a single variable that varies across the urban landscape. With a measure of the recreation alternatives available to homebuyers when they select each location, it is possible to isolate the effects of changes in ecological services as they affect local recreation. This strategy also does not preclude considering how amenities contribute to neighborhood attributes. These two terms are the elements isolated in equation (8). For our hedonic model, we adopt a semi-log specification for the price functions as in equation (11).[6] $q(d_i)$ is the distance proxy used to describe the neighborhood amenity effect of a resource that is described using a measure of the distance between the house and that resource.

$$\ln p_{ij} = a_o + \sum_{l=1}^{s} b_l a_{li} + g_1 \hat{E}u_{ji} + g_2 q(d_i) + u_i \qquad (11)$$

A measure bounding the welfare effects associated with changes in the ecological services water based recreation sites in urban watersheds can then be distinguished based

[5] This strategy does not require that we measure the opportunity cost of time. It can be assumed to be a source of unobserved heterogeneity. In separate research with this same sample we found that the opportunity cost of time can vary with the amount of time required for these types of outings (see Palmquist, Phaneuf, and Smith [2004]).

[6] Cropper, Deck, and McConnell's [1988] simulation experiments suggest that when the independent variables in hedonic models are replaced with proxy variables or the specifications are likely to be incomplete, simpler specifications for the price function such as the semi log have superior properties based on estimates of the marginal willingness to pay.

on how the change in q influences Eu_j. With the semi log form these would be given in equation (12).[7]

$$\Delta B_{rec_{ij}} = q \cdot g_1 \cdot p_{ij} \cdot \left[Eu_{ji}\left(q^1\right) - Eu_{ji}\left(q^0\right) \right] \qquad (12)$$

$\Delta B_{rec_{ij}}$ = estimated bound for annual benefits from change from q^0 to q^1 due to the location specific recreation effects for market area j and property i

? = annualization factor

III. Data

Our analysis requires that three different types of information be combined consistently. The first involves information on the sales of private homes in Wake County, North Carolina. These data were obtained from the Wake County Revenue Department. This database includes detailed information on residential properties. However, the format for these data was often not compatible with economic analysis. A translation from administrative records to measures of structural features of the homes was an important first step in our research. For example, the county database has information on each home's floor plan. The pre-analysis of these records required calculating the number of squared feet in different uses in each home. The top panel of Table 1 provides definitions of variables derived from these sources. Most are self explanatory. A set of qualitative variables for the condition of the house were defined

[7] We could also consider how we would measure a bound for changes in site specific amenities. This process requires the definition of a distance equivalent change for the change in q.

$$\Delta B_{nam_{ij}} = q \cdot g_2 \cdot p_{ij} \cdot \left[q\left(d^1\right) - q\left(d^0\right) \right]$$

$\Delta B_{nam_{ij}}$ = bound for annual benefits from change from d^0 to d^1 *hypothesized to* capture the neighborhood amenity effects of the changes from q^0 to q^1

based on ratings of the physical condition of the structure, rating from A (the highest score) to D (the lowest score).[8]

The second set of information was derived from a mailed survey to homeowners. Using the records of home sales from 1992 to 2000, we selected owner-occupied properties with sales prices greater than $50,000. Our sampling plan took advantage of realtor defined sub-markets. There are nineteen zones identified by the Triangle Multiple Listing Service as relatively homogenous sub-markets.[9] These areas will be labeled as the MLS zones. Figure 1 displays a map of the county with the spatial boundaries for each zone. For the selection of our sample, these areas were combined into four larger contiguous zones (i.e., approximately dividing the county into four quadrants). 9,000 records were drawn randomly from the records satisfying our initial criteria. The resulting sampled units were then evaluated to assure a sufficient number of observations in each of the sub-hydrologic units identified in a detailed separate analysis of the watersheds in Wake County by a private consulting firm (see CH2MHill [2003]). The sub-areas defined for this assessment are given in Figure 2.[10] There are 81 sub-hydrologic units in the CH2MHill classification scheme. When the initial sample did not have 20 observations in a sub-hydrologic area, we evaluated the set of housing sales that remained after drawing our initial sample of 9,000. If there were sufficient remaining housing sales in the relevant zones, we randomly selected additional observations to raise the number in each area to 20. If there were an insufficient number of sales, we simply

[8] A very small number of sales were of houses rated E. These were combined with rating D before the sample was drawn.
[9] We analyzed the hedonic price function in two ways - as a single price equation for one equilibrium based on structural attributes, but with our index of area specific opportunities as a determinant of price, and alternatively as a price function with fixed effects for each sub-market. Then we evaluated the determinants of these fixed effects (see below).
[10] Because the hydrologic zones are generally smaller than the MLS zones, this restriction also assured reasonable sample sizes for each MLS zone. See table 1A in the Appendix.

selected all that met our criteria. Each owner's name and address was verified using the current Wake County Property tax records. Only observations where the sales record from our hedonic database could be cross-linked to the currently listed owners were included in the sample.

A mailed survey was designed to collect information about each homeowner's socio-economic characteristics, recreation behavior, and leisure time choices. One aspect of the design of the questionnaire involved collecting information about whether homeowners considered water-based recreation sites and their attributes in making their housing choices. To address this issue we conducted two focus groups.[11] These discussions lead to the definition of a new class of recreation trips – which we designate here as local outings. These trips are short excursions involving a few hours.

Surveys were mailed to 7,554 households with valid addresses where we also had complete sales and property characteristics. Two mailings and a reminder postcard were sent to each selected homeowner (i.e., following the Dillman [1978] format for mailed surveys). Our survey took place between May 2003 and September 2003. We realized a 32% response rate, based on completed valid responses in comparison to the mailing reaching the intended addresses.[12] Each survey packet contained the survey

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[11] Two focus groups were conducted as part of the background research to develop the survey. The first took place July 23, 2002 with 10 homeowners. The years they lived in Raleigh ranged from 5 to 36 years. The second was October 9, 2002 with 14 individuals. Members of this group have lived in the area between 2 and 26 years. The focus groups identified local outings as the primary type of recreation that would be influential for selecting among neighborhoods in Wake County. Participants did not feel location would be important to trips that involved a longer time period.

[12] To gauge the potential for selection effects we used information from the 2000 Census at the block group level to estimate a grouped logit model with the fraction returning a questionnaire specified to be a function of the socio-economic characteristics of each block group. The results suggest areas with higher proportion of white residents, in areas with older homes, and with residents that lived a longer time in the area were more likely to return the questionnaire. There was some evidence that the response rates might be lower from high income areas. The full results (with *z* statistics in parentheses) are given as follows:

fraction responding =	1.724 percent white	+ 0.159 median number of rooms
	(6.73)	(1.94)

questionnaire, a letter, a map, and a legend for the recreation sites (as well as the opportunity to identify sites not listed on the map). Appendix A provides the survey assignments and the proportion returned by MLS zone.

The survey design allows each of these two databases (i.e. the residential housing sales data and the household survey) to be linked (via the latitude and longitude of each residence) to a set of geo-coded records developed for each of the over 200 recreation areas. These sites were identified in the survey. They are the sites listed by the survey respondents as the places for their recreation trips. The records for the housing sales, survey responses, and the locations, plus the travel time and distance to each recreation site, can also be linked to a separately developed database that is the third component of our analysis.

The last database includes records for water quality readings for the county. The water quality data combine twelve separate databases with technical indicators of water quality characteristics.[13] Our analysis in this paper is intended to be a first stage

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+ 0.021 median house age	- 0.039 median amount of time in area
(3.83)	(-2.27)
+ 0.022 x 10^{-5} median house value	- 0.091 x 10^{-5} median income
(1.50)	(-1.45)
+ 33.976	
(1.28)	
Pseudo R^2 = 0.018	

[13] Two are chemical monitoring data obtained from the N.C. Department of Natural Resources. These include monthly readings form 1994 to 2000 for 61 variables. The definitions of the factors that are measured and the method used are documented based on available records. These reports were supplemented with the paper records required for major NPDES point sources. Nine variables were collected from the monthly reports of these sources for the Neuse River. Four types of biological databases are included. Single samples collected on benthic and habitat, characteristics in August 2001 by CH2MHill for Wake County, and periodic readings for the state benthic communities were collected by N.C. Division of Water Quality from 1982 to 2003 for the sites in the Neuse River Basin and from 1983 to 2001 for the Cape Fear River Basin. Chemical data for four variables describing water quality for major lakes in the Neuse and Cape Fear watersheds are available periodically from 1981 to 2002. Chemical data for the upper Neuse River Basin with 89 variables are reported monthly over the period 1990 to 2002. The U.S. Geological Survey (USGS) also report chemical and flow data for sites within the upper Neuse and Cape Fear basins monthly from 1989 to 2001. This database includes 33 variables. Chemical and flow data for

evaluation of the basic logic of the model. As a result, we focus on only two of the available variables – a measure of the percent of the land area in each MLS zone covered with impervious surface, and a qualitative variable recoding the CH2MHill rating of the sub-hydrologic units in the county.

IV. Results

A. Describing Local Recreation Choices: RUM Estimates

The first step in developing our index for the role of local recreation alternatives available to homeowners involves modeling local outings. As we noted, a simple random utility model is used to describe these choices. We develop separate models for each of the 19 housing market areas identified by the Multiple Listing Service. This strategy is possible because our survey elicits for each sampled homeowner a record of three types of recreation trips to water based recreation sites. Our questionnaire asks about the recreation trips taken during a seven month period from May through November 2002. The trips are distinguished as: short outings that involve less than four hours away from home; day outings involving a full day of activity but no overnight stay; and experiences that involve two day trips with an overnight stay. The number of each type of trip, the sites used, and activities undertaken are each recorded separately. Over two hundred locations were identified by the sample respondents. Each site was geo-located with a latitude and longitude. As described in the footnotes to Table 1, distance and travel time measures to every possible site were estimated for every sample respondent.

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the lower Neuse River Basin are available in the LNBA database monthly from 1994 to 2002. Finally, the USGS flow data for upper Neuse River Basin was assembled monthly from 1990 to 2002. All these databases can be linked either through the latitude and longitude of the sampling location or other identifying information to our various geographic area definitions.

For the random utility models estimated to develop our index of recreation opportunities, we define a zone specific choice set with all the sites identified by homeowners in each MLS zone. Each random utility model provides the basis for an index of the local recreation alternatives homebuyers are assumed to consider in evaluating the selection of a residential location. We assume new buyers will focus on the recreation sites that current residents use. Each of the zone specific choice sets varies in size and composition. While our questionnaire did limit the space for reporting sites used to seven alternatives, none of the individuals identified more than 6 sites for local outings. The average number identified by a respondent who took local outings was about 2 sites for each zone. This count offers a potentially interesting way to consider the differences among the recreation trips in our survey. The count of sites an individual reports that she uses reflects both her desire for variety and the supply of recognized alternatives to meet each type of recreation.

While local outings are the focus of our recreation demand models, a comparison of the factors influencing the stated number of sites used for each type of recreation helps to confirm that people do consider these types of trips as distinct. Table 2 provides a simple multivariate analysis of the reported counts of the sites used for each type of recreation based on a Poisson regression model. The second column provides the results for local outings. Columns three and four report the findings for one day and two day trips respectively. Several socio-economic characteristics display different influences on the three types of trips. The most notable of these is income, which has a significant (with a p-value of 0.10) negative influence on the number of places respondents report for their local outings, but the opposite effect for longer trips. Age and boat ownership have consistent effects on all three types of recreation. Small children appear constraining for day trips but do not have an impact on the number of sites selected for other types of recreation. Other variables such as respondent reports of appreciable time limitations do not affect the count of sites listed but may well affect behavior in other ways. The distinctive roles for income, race, and small children in these summaries suggest people appear to evaluate the choice alternatives differently for each type of recreation.

Our simple random utility models for local outings follow the logic outlined in equation (8). Trips are assumed to be independent choices. Travel time was considered to be the primary "cost" of a local outing. We also add to this specification two measures of the quality of the watershed that includes the site. The first of these measures is the estimated percent of the land area covered with impervious surface. Schueler [1994] and Cappiella and Brown [2001] have suggested this measure can serve as an indicator to predict the negative effects of development-related changes in land cover on aquatic systems. In addition, we use an expert rating of each sub-hydrologic zone as a second indicator. More specifically, as we noted earlier, in 2003 a private consulting firm, CH2MHill, completed a commissioned study of Watershed Quality. Wake County had requested a study to evaluate the county's streams and watersheds as part of a planning process intended to balance economic development with natural resource conservation and environmental protection.

Three categories of information were assembled for their assessment: chemical data on stream quality and concentration of pollutants, biological data on the number and types of species sensitive to water quality, and physical characteristics related to habitat and geomorphology. Eight-one sub-hydrologic units were classified into healthy, impacted, and degraded. The breakdown is given as follows:

Rating	Number of Sub Hydrologic
Healthy	30
Impacted	38
Degraded	13

We coded a qualitative variable to distinguish sites in degraded hydrologic areas. All of the sites visited for local outings were either degraded or impacted.

Table 3 provides the estimated random utility models for six of the nineteen zones. In all of these cases, increases in travel time to reach a site reduced the likelihood of selecting it.[14] The signs for both the impervious surface measure and the qualitative variable for degraded conditions varied across models estimated for each MLS zones. In the case of the impervious surface measure, the majority of the estimated parameters were negative and most of these were significantly different from zero. The qualitative variable rating sub-hydrologic units (based on the CH2MHill evaluation) was less stable – with both positive and significant and negative and significant estimates. Our a priori interpretation of these variables implied that both would have negative effects on the likelihood of visiting the recreation sites in areas with these conditions. Nonetheless, it is important to acknowledge that both watershed quality measures refer to spatial zones that include the recreation sites. They are not specific indexes for each site.[15]

Despite the mixed record for the influence of these watershed measures on site choices, the overall effect of impervious surface on our index of water-based recreation

[14] For the remaining zones, only one case resulted in a positive estimate for the travel time parameter.
[15] In future research we plan to consider linking the available technical measures of water quality in our database to each site. However, it is also reasonable to ask how the people selecting these sites would know about these detailed measurements and use them to evaluate the water quality conditions. This issue will be considered in our further research with the Wake County Database.

opportunities provided by each neighborhood is consistent with *a priori* expectations. That is, when we consider the mix of sites selected by our sample respondents in each MLS zone and compute the average value for the expected maximum utility terms (i.e. equation (10)), the index declines with increases in the impervious surface in the MLS zone visited for short outings. Equation (13) provides a simple regression of the value of our index of opportunities on the average impervious surface in the zones with sites visited.

The numbers in parentheses below the estimated parameters are t-ratios.[16]

$$\overline{E}u_j = \underset{(1.73)}{31.50} - \underset{(-1.85)}{2.57} \text{ Percent Impervious Surface}_j \tag{13}$$

$$n = 19$$
$$R^2 = 0.17$$

The estimates for the expected maximum utility (or the average log sum), $\overline{E}u_j$, corresponds to the selections by respondents in each MLS zone, weighted by the parameters from the zone specific random utility model. The average measure for impervious surface considers the values for the MLS zones *visited* through the selection of sites for local recreation. It is a trip weighted average of these measures. This expression indicates that the overall pattern described with the index is what we would have expected. Recreation opportunities are given a lower (quality adjusted) "score" when there are higher proportions of the land areas in impervious surface in the locations of the sites visited. There was no significant association when the same analysis was

[16] This model is not intended as a test, since the dependent variable is defined using values of the independent variable from a set of RUM estimates. It is a convenient summary of the net outcomes of the reported choices in each MLS zone. The objective is to evaluate whether the recreation quantity index signals to property markets consistently the quality of the recreation sites being selected. In this case it describes whether increases in the weighted average value for the impervious surface measure are associated with declines in our quality adjusted index for recreation opportunities.

conducted using the average log sum and the average scores based on the CH2MHill rating.

B. Hedonic Property Value Estimates

Table 4 provides the estimates for our hedonic model, based on sales in 1998 and 1999 using a semi-log specification. The second column reports the estimated effects of structural characteristics along with two measures of water quality related effects. The first of these is our quality adjusted index of "value" of access to recreation sites for local outings, based on equation (10) and the 19 estimated random utility models. The second is an index of general water based amenities that are also hypothesized to be relevant for each neighborhood. It relies on the conventional logic that if a house is located on or near a lake this proximity may be an amenity for the residents, which may influence property values. To compute this measure, we used Wake County GIS Services to provide an Arcview shapefile of all lakes in the county. The distance of each house from all lakes was calculated and the distance to the nearest lake was determined. Since the amenity effect of lake proximity would decline rapidly with distance from the lake and would fall to zero at some distance, an index for lake proximity was developed. The

Lake Distance index = $\max\left\{1-\left(\frac{d}{d_{\max}}\right)^{\frac{1}{2}};0\right\}$, where d is the distance of the house from the nearest lake and $d_{\max}$ is the maximum distance where the lake has any effect on the house value. This index is between zero and one and is convex. As noted in table 1, a value of 2,640 feet (one-half mile) was used for $d_{\max}$. The third column reports the means for each of the conventional housing attributes as well as for the sales price (in the row corresponding to the intercept for the model).

Both measures of the effects of watershed related amenities are significant, positive determinants of property values. This result suggests that the effects of the quality adjusted recreation index can be distinguished from a more general index of the neighborhood related amenities provided by urban watersheds.[17] All of the other structural variables in the model (with the exception of an indicator variable for the presence of a swimming pool) are significant determinants of the sales prices. The only potentially implausible relationship implied by the estimates is for the measure of average commuting time. We expect that increases in commuting time to work associated with the different home sites would reduce property values. However, this measure could easily be serving as a proxy variable for the more rural areas in the county and, as a result, reflect the influence of rural amenities which would also imply greater distances from employment centers and longer average commutes.

Thus, the hedonic estimates provide strong confirmation for our efforts to distinguish the long and short run aspects of the influences amenities have on individual behavior. Our framework implies that a model that describes the role of housing choices as conditioning factors influencing short term recreation decisions addresses the "double

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[17] Our quality adjusted index for the amount of each recreation is the average of the expected maximum utilities as defined in equation (10). Assigning this to all housing transactions based on their MLS zone might arguably introduce an errors-in-variables problem (see Moulton [1990]). To evaluate whether this interpretation affected our estimates for the role of $\hat{E}u$, we considered an alternative estimation strategy. We estimated fixed effects for each zone in the hedonic model and then used the estimated fixed effects in a feasible GLS (using the relevant partition matrix from the OLS variance covariance matrix for the covariance matrix, see Nevo [2001] as an example). The estimated effect for the recreation index is nearly identical to the one step hedonic findings (t-ratios are in parentheses)

$$\underset{}{\text{MLS\_Fixed\_effect}} = \underset{(2297.6)}{10.881} + \underset{(32.271)}{0.004}\,\hat{E}u$$

counting" concerns raised by McConnell [1990]. Moreover, with information on recreation choices it is possible to consistently estimate the distinct roles for neighborhood amenities and the amenities conveyed through local recreation in an integrated framework.

C. A Policy Application

One important use of hedonic property value models is for estimating bounds for the tradeoffs homeowners would be willing to make to improve the amenities available in their neighborhoods. We can use this logic to evaluate the plausibility of our estimates for the effects of access to, as well as the quality of, local recreation sites. Equation (12) provides the algebraic description of the logic involved. To make the analysis tangible we selected a recent proposal to expand the capacity of a waste water treatment plant serving a growing community, Butner, NC, that is outside Wake County.[18] However, the change would influence important watersheds in the county. The expansion would increase the plant discharge from 5.5 to 7.5 million gallons daily. This increase implies that nitrogen loadings into a tributary of the Neuse River would double.[19] The Neuse Watershed is the most important in Wake County. This river also is the source for water to Falls Lake, one of the popular recreation sites in Wake County, and a drinking water source for homeowners in Raleigh and elsewhere in the county. The lake has already

[18] Our description is based on newspaper accounts of the proposal in *The Raleigh News and Observer*, August 5, 2004, August 7, 2004, and September 24, 2004.

[19] The proposed increased discharge from the Butner waste water treatment plant is possible under current regulations because the Butner facility purchased emission permits from the Bay River Metropolitan Sewage District near the mouth of the Neuse River. The emissions from the Bay River facility are, for practical purposes, directly into the Pamlico Sound at New Bern, N.C. The purchase of 6,113 pounds of this facility's permits translates into 61,130 pounds 200 miles up river because it is estimated that only 10 percent of the added nitrogen up river would reach the end of the Neuse. The permits are defined exclusively on the basis of nitrogen entering the estuary. They do not consider the intermediate effects of increased discharges on the river and ecosystem throughout the 200 mile stretch.

begun to experience water quality problems even without this expansion. The upper portion of the lake has measured concentrations of chlorophyll A, exceeding state standards. Chlorophyll A is related to algae blooms and water quality. Increased nutrients will accelerate these problems.

To illustrate how our linked model can be used to consider the effects of this change, we assume that granting the expansion permit would imply Falls Lake was no longer an attractive recreation site for local outings due to the continued degradation associated with the increased nitrogen loadings into the lake. To represent this change we removed Falls Lake from the choice set describing available sites in each of the 17 MLS zones where it was a choice alternative. This process allows us to compute the change in expected maximum utility, our quality-adjusted index of the "quantity" of local recreation opportunities available to each housing market. We then use the estimated hedonic price function to compute an upper bound for homeowners' annual willingness to pay to avoid this change. Our estimates use the adjusted predictions for the housing prices and a five percent rate to compute the annual estimate of the bound for the willingness to pay.[20]

Table 5 reports these estimates in the second column along with the proportionate change in the expected maximum utility (in the third column), the average sales prices for housing by MLS zone (in the sixth column), and some other information to gauge the importance of the Falls Lake site for the survey respondents in each MLS zone. These summary statistics are given in the last four columns. First, we list the total number of local outings reported to be taken by our survey respondents and the average per

[20] The adjusted price is an approximation to reduce the bias in predicting the price from a semi log model. For simplicity we assume housing is completely durable, so the annual value is the discount rate times the sales price.

respondent in the seven month period covered by our survey. To evaluate the potential importance of Falls Lake to these residents, we also computed the number of these outings that were to the Lake and the average outings per user. Economic importance is not exclusively associated with the count of trips. It will also depend on the alternatives available with comparable proximity and quality.

Comparison of the values measured for the loss together with the total outings versus the outings to Falls Lake confirms this conclusion. Some of the larger values arise when there are a number of outings to other sites, as in the case of MLS zones 2, 4, and 7. The Falls Lake site makes an important contribution to the quality adjusted index of the amount of recreation opportunities available in an area, thus relying on the pattern of use alone would be misleading. Of course, the largest values for MLS zone 14 (close to the Lake) arise where residents perceive few alternatives.

Finally for comparative purposes we report the average value for the change in per trip consumer surplus (also in 1998 dollars) due to the loss of Falls Lake as a choice alternative by MLS zone. This estimate is based on each zone's random utility model and the change in the expected maximum utility with and without Falls Lake in the choice set. There are two added steps required to compute it. First, the difference in the average log sums with and without Falls Lake is divided by the absolute magnitude of the parameter estimated for travel time. We could consider this ratio as expressing the willingness to avoid the loss, in time units – the amount of free time a person would give up rather than close Falls Lake from their choice set. To monetize this time, we make use of some related research with this same sample (see Palmquist, Phaneuf, and Smith [2004]). This work hypothesized that the opportunity cost of time varies based on the amount and timing of the time required for recreation. We use the time allocations of our survey respondents along with their willingness to pay to substitute market services for some home production to estimate this opportunity cost. Our analysis suggests the marginal opportunity cost varies with the amount of time required. For these computations we used the marginal value for a 4 hour trip and adjusted the estimated parameters for time costs. Using this average value by MLS zone (and given in column six) together with the willingness to give up time, it is possible to develop an approximate estimate of the per trip consumer surplus. If we scale this willingness to pay by the average number of outings taken by our sample respondents to all sites (given in column eight) we see the product is generally less than the long run value implied by the hedonic estimates. While there is no reason to expect the short run and long run estimates would be equal, there is clear consistency between the two. More specifically, the two methods are monetizing the same increment in the index for the change in recreation opportunities. The hedonic uses the long run market capitalization of these opportunities (in annualized terms) by the housing market. The monetizing of the same index uses another market – based on labor/leisure choices and time allocation choices when respondents were offered short run options for adjustment. In the absence of uncertainty and with limited adjustment costs, we could specify an envelope condition that would imply equality in these values.[21] The close correspondence for our approximation implies there is scope for using housing markets together with structural models of how ecosystem services contribute to people's activities in developing revealed preference estimates for fairly complex patterns of spatial effects on behavior, provided we can rely on people observing how these services contribute to the quality of their activities.

[21] This condition is what McConnell [1990] was implicitly describing.

V. Implications

Measuring people's valuation of water quality and watershed services with hedonic property value models has proved difficult. Leggett and Bockstael [2000] suggest that despite consumers' reports indicating they want to live near water resources for the recreational opportunities they offer, there are often few opportunities for analysts to observe sufficient local differences in recognizable water quality conditions to measure their effects. As a result, these authors highlight the distinction between the geographic extent of the housing market and the likely spatial variation in water quality conditions. To estimate consumers' responses to differences in the services provided by improved water related resources within a hedonic framework there must be sufficient variation in the measure hypothesized to characterize these services. Often this is not the case. Properties on a single lake are unlikely to experience markedly different water quality. Their analysis of the sales of waterfront properties on the western shore of the Chesapeake Bay was successful in estimating a water quality effect using a distance weighted average of and index for the bacterial contamination (i.e. the fecal coliform counts from 104 monitoring stations). The water quality measure exhibited sufficient spatial variation to evaluate its effect on coastal property values. Mahan et al. [2000] also found that proximity to streams, lakes and some types of wetlands increase property values in Portland. However, their efforts to estimate second stage inverse demand models were not successful. They also acknowledge the important role the spatial extent of the market plays in these types of analyses.

Our research suggests that there are several distinct roles for the services of environmental resources. A single proxy index is unlikely to be able to adequately reflect all of them. One of the first of these roles is as a neighborhood amenity. This contribution is the one most widely recognized in the hedonic literature. A second role often acknowledged in discussions of the importance of ecological services but with little specific discussion in the hedonic literature arises when their services make a supporting contribution to other activities. Some of these involve people and their outdoor recreation trips. Others involve related natural resources, such as groundwater, whose quality and recharge rate can be influenced by the characteristics of watersheds.

The spatial boundaries relevant for these various influences across different sets of activities need not be the same. Neighborhood amenity effects are likely to be associated with the immediate proximity of a house, as our index of access to close lakes implied. It is less clear how to characterize the roles for other influences. Most hedonic studies have relied on some distance based index. We have suggested an alternative approach.

Our framework considers the decisions used in revealed preference models applied to environmental services as alternative strategies to recover information about the importance of these services to people. Each describes a different choice margin. To integrate their results, the various choices must be described consistently. In this paper we used the long run/short run distinction to integrate local recreation choices with residential housing decisions.

Efforts to propose some type of integration are not new to non-market valuation. One was the basis for Cameron's [1992a, 1992b] proposal to use revealed preference behavior to impose "budget discipline" on the stated preference choices people make for the same resource. A proposed strategy for integration is also the basis for the maintained assumptions that Smith, Pattanayak, and Van Houtven [2002] use to calibrate preference functions for benefit transfers. In our case here, however, there is an important distinction. Revealed preference models are used to construct a quantity index that collapses the recreation opportunities available to those living in a neighborhood. This index is derived from a model of recreation demand. The model reduces the complexity of all the attributes and availability measures for the local recreation sites into a consistent quantity index. It also defines the spatial domain of influence through the choice set of recreation sites considered relevant for the model.

The equilibrium housing price will be influenced by this index because the opportunities differ across the neighborhoods comprising a housing market. McConnell [1990] describes this prospect as a potential source for double counting. He argues that property values capitalize the expected future values derived from the available recreation services due to a location. Our use of the expected value of the maximum utility available from a recreation choice set is consistent with his suggestion that it is not a large leap to propose that "…the present discounted value of pollution damage from an ex ante concept, containing valuation of expectations of future choices" (p. 126). The potential for connections does not stop here. Rather, our proposed logic offers the means to consider other watershed services, provided there is a basis for using current choice margins to describe how these services contribute to current decisions.

Our empirical example exploits prior information describing the types of recreation likely to be associated with choices among alternative housing neighborhoods.

The measure of these recreation alternatives in a location was a consistent and significant determinant of housing prices and the specification also controls for the effects of more general amenity effects of proximity to local water resources. We developed estimates for the value of avoiding the loss of a popular recreation site in the northern portion of Wake County using both the hedonic bounds and the random utility models. The results are consistent with interpreting the hedonic as ex ante bound for the incremental value of the expected future services from protecting the lake.

Table 1: Primary Variables for Empirical Analysis

Name	Definition
A. <u>Hedonic Variables</u>	
lprice	Natural log of sale price of property
baths	Number of bathrooms
regheatarea	Main heated living area in square feet
age	Age of structure, calculated as sale year-year built
acreage	Lot size in acres
sewer	Community sewer system
bsmtheat	Basement heated area in square feet
atticheat	Attic heated area in square feet
encporch	Enclosed porch area in square feet
scrporch	Screened porch area in square feet
opnporch	Open porch area in square feet
garage	Garage area in square feet
Deck	Deck area in square feet
fireplaces	Number of fireplaces
detgarage	Dummy variable indicating presence of detached garage
walldum1	Dummy variable indicating presence of brick walls
bsmtdum1	Dummy variable indicating presence of full basement
bsmtdum2	Dummy variable indicating presence of partial basement
floordum1	Dummy variable indicating presence of hardwood floors
poolres	Dummy variable indicating presence of residential swimming pool
condadum	Dummy variable indicating house is of condition A (highest)
condcdum	Dummy variable indicating house is of condition C
condddum	Dummy variable indicating house is of condition D
commuting time	Average travel time to work computed for workers 16 years and older by block group based on 2000 census
Lake Distance Index	this variable is measured in feet as the $\max\left[1-\left(\frac{d}{d_{\max}}\right)^{1/2},0\right]$ where d is the distance of each house to the nearest lake and $d_{\max}$ is the maximum distance, assumed to be ½ mile (2,640 feet)
B. <u>Recreation Variables</u>	
Travel time	Time in minutes for one way trips from respondent's home to recreation site[a]

[a] The travel time and travel distance between each survey respondent's house and each recreation site were calculated using the PCMiler software. PCMiler calculates distances between lat/long points along a road network, and then estimates travel times using speed limit information. It has been commonly used in travel cost models to calculate travel distances and times, however it is designed for the trucking industry.

Distance	One-way distance in miles from respondent's home to the recreation time[a]
C. Watershed Variables	
Percentage Impervious Surface[b]	Measure of fraction of land area in MLS zone covered with impervious surface
Sub Watershed Rating	Classification of 81 sub-hydrologic units in Wake County as healthy, impacted, or degraded, based on the CH2MHill evaluation of the state of the County's watersheds
D. Household Survey	
less high	qualitative variable = 1 if less than high school education
Finc	family income (in dollars)
male	qualitative variable = 1 if respondent is male
white	qualitative variable = 1 if respondent is white
age of respondent	age in years
children less than 6	number of children less than 6 years of age
time_limited	qualitative variable = 1 if respondent indicates leisure time is limited
boat_own	qualitative variable = 1 if respondent owns a boat

Thus one of PCMiler's drawbacks is that the road network it uses to calculate the times and distances is composed of roads that are accessible to trucks. The error in estimating travel times and distances using a network of major roads accessible to trucks is likely to be largest for the sites used for local outings.

To decrease the measurement error that might be introduced with PCMiler in these cases, an alternative strategy was developed using Arcview. Using a comprehensive road network including minor roads developed by "Tigerline" (Census 2000 TIGER/Line Data is provided by the U.S. Bureau of the Census) for Wake County, travel times and distances from survey households to local recreation sites were calculated within Arcview. One exception was the calculation of times and distances to Jordan Lake, a popular local recreation destination located just outside of Wake County. By calculating the travel time and distance to the County line, and the adding this time and distance to the PCMiler estimate from the county line to the site, a more accurate time and distance was generated to this recreation site. To determine if the other Arcview estimates were more accurate than the PCMiler estimates for the local recreation site, a sample of 20 households and 10 recreation sites were compared to estimates produced by Mapquest, an online service that also uses major and minor roads in their calculations. Based on Sum of Squared Errors, it appears that the Arcview estimates were more accurate than the PCMiler estimates for the local recreation sites. Thus we replaced the PCMiler times and distances with the Arcview times and distances for local recreation sites.

[b] To create a measure of percent imperviousness for other geographic areas in our study, we used the same procedure employed by CH2MHill. Land use types were classified into 17 classes. We used the CH2MHill estimates for percent impervious surface measures for each of the 17 land use classes. The amount of each land type in each area was then weighted by these percentages to measure the impervious surface for the geographic area of interest.

Table 2: Determinants of Count of Sites Used by Type of Recreation Trip[a]

Independent Variables	Local Outing	Day Trip	Two Day Trip
less high (= 1)	-0.142 (-0.40)	0.114 (0.25)	0.382 (0.85)
Finc	$-0.067\text{x}10^{-6}$ (-1.94)	$-0.022\text{x}10^{-6}$ (-0.47)	$0.073\text{x}10^{-6}$ (2.10)
male (= 1)	-0.041 (-0.93)	0.033 (0.53)	-0.060 (-1.23)
white (= 1)	0.116 (1.64)	0.085 (0.85)	0.262 (3.07)
age of respondent	-0.013 (-5.18)	-0.013 (-3.75)	-0.010 (-3.65)
children less than 6	-0.023 (-0.80)	-0.144 (-3.20)	-0.014 (-0.45)
time_limited (= 1)	0.030 (0.57)	-0.009 (-0.13)	-0.029 (-0.50)
boat_own (= 1)	0.263 (4.80)	0.586 (8.49)	0.296 (5.11)
intercept	0.807 (5.93)	0.232 (1.22)	0.178 (1.19)
no. of observations	1572	1354	1641
pseudo R^2	0.013	0.028	0.015

[a] These estimates are based on a Poisson regression model with the number of recreation sites treated as a count variable. The numbers in parentheses are ratios for the estimated coefficients to their asymptotic standard errors.

Table 3: A Sample of Random Utility Models by MLS Zone

Independent Variables	MLS Zone [a]					
	1	5	7	14	15	18
Percent Impervious Surface	-0.035 (-3.71)	0.032 (4.97)	-0.306 (-26.27)	-0.028 (-1.11)	0.005 (0.69)	-0.215 (-7.57)
CH2MHill Rating = Degraded (=1, 0 otherwise)	0.773 (8.25)	0.333 (7.92)	3.406 (23.89)	-0.645 (-2.03)	-0.863 (-6.93)	2.882 (9.241)
Travel Time	-0.070 (-8.32)	-0.109 (-30.94)	-0.126 (-36.66)	-0.138 (-13.37)	-0.193 (-19.99)	-0.125 (-14.39)

[a] The numbers in parentheses are the ratios of the estimated parameters to its estimated asymptotic standard error for the null hypothesis of no association.

Table 4: Hedonic Property Value for Sales in 1998 and 1999

Independent Variables	Model[a]	Means[b]
Index of Recreation Access[c]	0.004 (28.56)	–
Lake Distance Index[d]	0.014 (2.57)	–
age	-0.002 (-17.54)	11.37 (15.06)
baths	0.036 (23.97)	2.46 (0.68)
acreage	0.042 (29.84)	0.45 (0.62)
regheatarea	0.039×10^{-2} (204.43)	1,914 (681.24)
detgarage	0.085 (18.83)	0.03 (0.17)
fireplaces	0.068 (29.16)	0.91 (0.34)
deck	0.019×10^{-2} (33.42)	159.35 (145.05)
sewer	0.013 (5.60)	0.83 (0.37)
floordum1	-0.015 (-4.35)	0.10 (0.30)
scrporch	0.034×10^{-2} (25.40)	16.78 (55.88)
atticheat	0.023×10^{-2} (42.96)	43.21 (142.27)
bsmtheat	0.058×10^{-3} (11.22)	48.39 (199.66)
garage	0.030×10^{-2} (69.80)	289.46 (248.82)
poolres	0.006 (0.76)	0.01 (0.09)
bsmtdum1	0.133 (30.93)	0.052 (0.221)
bsmtdum2	0.138 (35.70)	0.063 (0.243)

[a] The numbers in parentheses are t-ratios for the null hypothesis of no association.
[b] Numbers in parentheses are standard deviations.
[c] The Index of Recreation Access corresponds to the average values across properties sold for the log sum derived from the parameter estimates for the random utility model associated with each house's MLS zone.
[d] The Lake Distance Index is $\max\left[1-\left(d/2650\right)^{1/2};0\right]$ with d the distance from the home to the nearest lake.

walldum1	0.038 (14.22)	0.113 (0.317)
encproch	0.196×10^{-3} (7.32)	3.72 (28.11)
opnporch	0.169×10^{-3} (19.10)	68.46 (85.17)
condadum	0.231 (62.58)	0.06 (0.233)
condcdum	-0.139 (-28.22)	0.03 (0.158)
condddum	-0.310 (-19.09)	0.02×10^{-1} (0.041)
commuting time	0.005 (47.50)	28.61 (8.37)
Year of Sale = 1999	0.036 (24.22)	
Intercept	10.853 (2,224.10)	180,202[e] (75,564)
no. of observations	38,725	
R^2	0.861	

[e] The average value of the sales price.

Table 5: WTP Bounds for Removing a Recreation Site

MLS Zone	Hedonic Bound for WTP[a]	Proportionate Change in Recreation Index	Benefits – RUM per trip[b]	Marginal Value of Time (per hour)	Average Housing Price	Local Outings – All Areas		Falls Lake Outings	
						Total	Per User	Total	Per User
1	1.49	0.039	0.30	32.24	208,851	920	5.75	82	3.7
2	3.40	0.090	0.31	27.18	188,630	3,414	10.25	485	6.6
3	1.59	0.061	1.18	45.25	107,387	143	4.09	13	6.5
4	7.32	0.235	0.37	20.96	136,030	854	8.80	6	1.5
5	0.16	0.004	0.02	28.78	207,699	3,150	7.93	54	2.8
6	0.15	0.006	0.01	20.85	123,880	523	7.58	4	2
7	12.87	0.279	1.15	31.12	225,316	2,058	6.77	958	8.3
8	3.03	0.106	0.14	25.72	134,764	698	5.97	118	5.1
9	0.57	0.014	0.08	19.74	195,453	1,124	4.89	21	3.5
10	–	–	–	18.33	232,327	657	7.30	0	0
11	1.34	0.049	0.28	26.77	123,567	333	4.01	56	4.3
12	17.31	0.830	0.48	28.89	104,258	96	4.00	47	5.9
13	10.31	0.332	–[c]	15.52	123,211	58	2.64	14	2.3
14	58.86	1.606	3.86	19.95	177,824	310	4.25	217	5.7
15	0.06	0.002	0.005	32.57	174,766	869	6.30	3	1
16	2.14	0.069	0.57	26.53	138,287	366	3.62	6	2
17	–	–	–	20.00	155,304	142	4.58	0	0
18	0.41	0.012	0.03	20.02	157,528	401	4.66	10	1.7
21	1.81	0.056	1.09	30.99	148,560	383	4.30	168	4.8

[a] These estimates are in 1998 dollars. They use the predicted price and adjust for the bias in converting from the predicted $\ln p$ to a predicted price.
$\hat{p} = \exp(\ln \hat{p}) \cdot (1 + \frac{1}{2}\text{var}(\ln \hat{p}))^{-1}$ (see Kennedy[1983] for further details).

[b] Converted to 1998 dollars using the Consumer Price Index.

[c] The estimated parameter for time cost of travel was positive for this model. As the seventh column indicates, this MLS zone had the smallest number of local outings generated, with only 22 users.

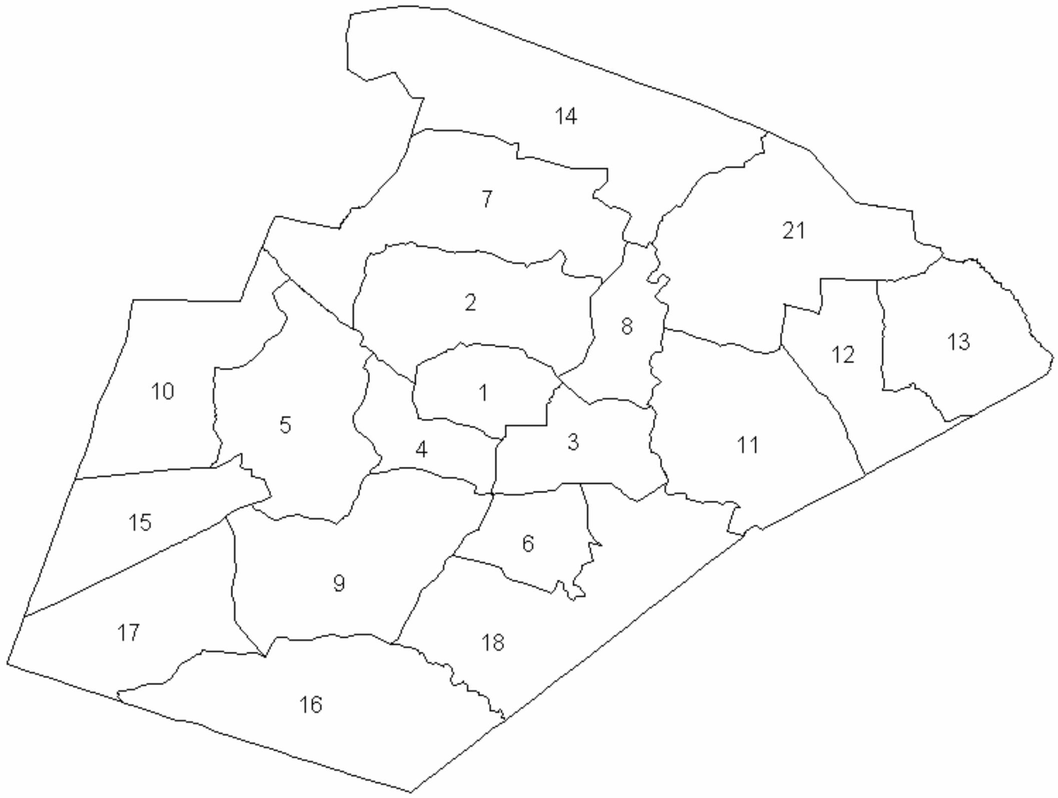

Figure 1: MLS Spatial Zones for Housing Submarkets in Wake County, NC

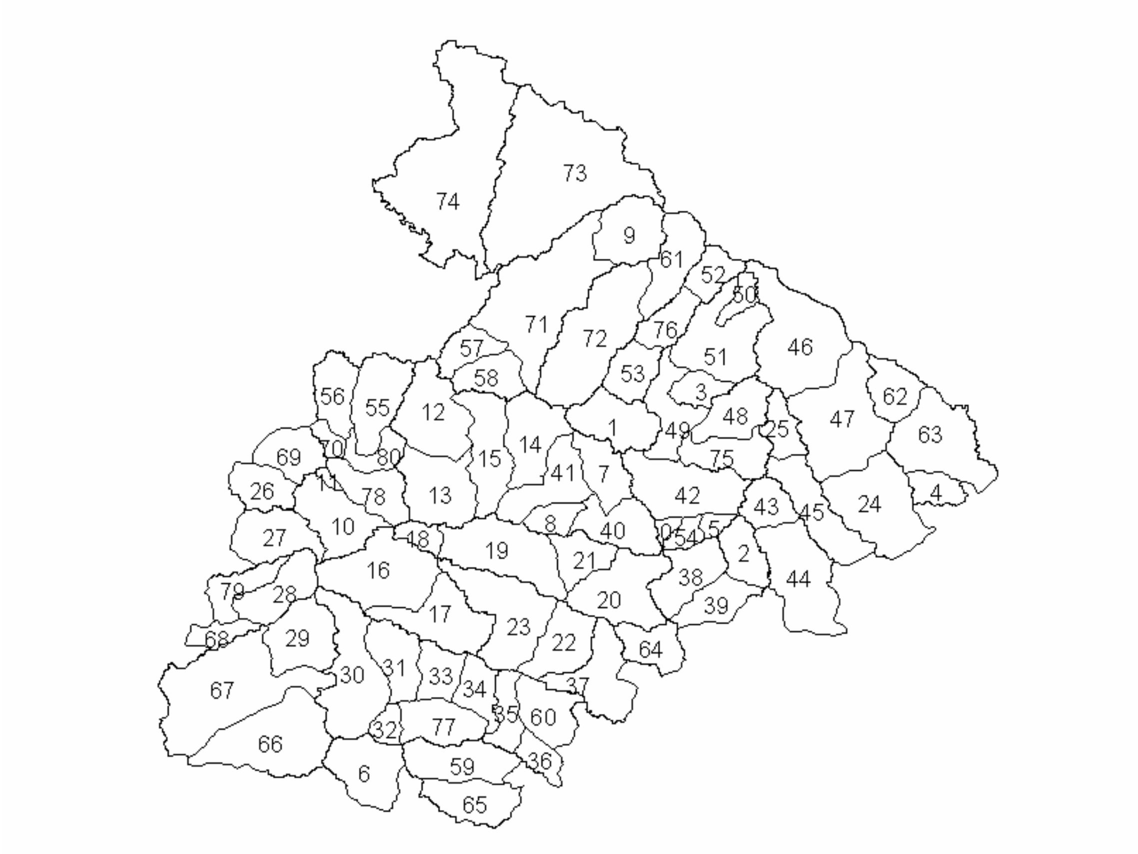

Figure 2: CH2MHill Zones for Disaggregated Spatial Units in Wake County, NC

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Appendix A

Table 1A: Survey Assignments and Returns by MLS Zone

MLS Zone	Surveys Mailed[a]	Surveys Returned	Proportion Returned
1	358	107	0.299
2	1055	334	0.317
3	289	101	0.349
4	179	62	0.346
5	1401	430	0.307
6	281	87	0.310
7	840	260	0.310
8	481	149	0.309
9	525	162	0.323
10	334	108	0.342
11	284	97	0.361
12	97	35	0.457
13	81	37	0.306
14	222	68	0.352
15	270	95	0.296
16	274	81	0.417
17	48	20	0.265
18	230	61	0.334
21	305	102	0.317
Total	**7554**	**2396**	**0.317[b]**

[a] Errors in record keeping caused the version number of four surveys to be omitted from the tracking system. As a result, they are included here but not used in subsequent analysis.
[b] Proportion returned for the county as a whole.

Session III: Keeping Water Fresh: The Value of Improved Fresh Water Quality
Discussant Comments -- John Powers
October 26, 2004

Summary of Egan et al.

The purpose of the research is to provide information on the recreational value of water quality improvements as a function of detailed physical attributes of water bodies. The research supports Iowa's effort to comply with Clean Water Act requirement to develop TMDLs for impaired waters. The policy effort involves identifying priority waterbodies and strategies for allocating resources through the use of cost and benefit information on remediation efforts.

The research includes developing a recreation demand (travel cost) model of recreational lake usage in Iowa. Unique data collected by Iowa State University's Limnology Laboratory an extensive array of physical attributes, including Secchi depth, chlorophyll, 3 nitrogen measures, phosphorus, silicon, acidity (pH), alkalinity, and 2 suspended solids measures. The researchers are also collecting site and household characteristics data .

The authors use a mixed logit model that integrates site selection and participation decisions in a utility consistent framework. They estimate model specifications that differ in the numbers of physical water quality measures in order to test for the stability of parameter estimates.

The estimated parameters are generally of the expected sign, with water clarity being valued highly. Some variation in water color is acceptable, but high algae levels lead to a reduced number of trips taken.

The results indicate that policy makers can maximize benefits by spreading improvements across the state, and by improving a smaller number of lakes to high quality rather than raising a large number of lakes to average quality.

Comments

Overall, this is a nice paper, but it is only a small fraction of the bigger project. I like the idea of testing to see how recreation demand is affected by physical characteristics of water quality. The results suggest people know about and respond to <u>easily observed</u> characteristics, especially water clarity. But, the impact of nitrogen is less observable, and also very valuable, since it affects the nitrogen-phosphorous balance, and has impacts in estuaries.

Several questions for the researchers

How does limited information about water quality affect the welfare estimates? Does the valuation <u>methodology</u> affect your answer (e.g., SP rather than RP)? Does knowing the source of contamination affect "value"?

Summary of Smith et al.

The purpose of the research is primarily methodological. The authors examine choice margins using hedonic and recreation demand (travel cost) models through integrated estimation of hedonic property values (long run decisions) and recreation demand values (short run decisions). Expected recreation benefits are viewed as a (public) attribute of home location. The results are used to estimate the impact (lost water quality benefits) of recent proposal to expand capacity of wastewater treatment plant serving a growing community (Butner, NC). In this example, the authors estimate willingness to pay to avoid the adverse impact on recreation and drinking water in Wake County, NC of nitrogen loads into the Neuse River.

This study attempts to estimate choice margins across a larger set of alternatives, by using hedonic and travel cost methods in an integrated manner. This analysis involves using GIS-based models and data, socio-economic data, water quality measure, property sales, and recreation data for over 2,000 households. Several indexes are used in this study, including a Watershed Quality Index , which is used to summarizes effects of watershed quality measures on local recreation opportunities, a Recreation Quantity Index (Index of Recreational Opportunities), which is used to capture the expected benefits from recreation, and a Lake Distance Index, which is an index of lake proximity, accounting for distance of the house from the nearest lake, and the maximum distance from where the lake has any effect on house value.

Comments

I like the idea of integrating different sources and types of benefit information, although I am concerned about the complexity. I also think the use of the indexes is quite interesting, though I would like to see greater attention given to index structure and theoretic rationale. Finally, does it matter whether we measure from the household location to the resource location, or vice versa?

General comments

The "commodity" definition is important to benefit transfer so that apples-to-apples transfers are possible. If we think of an ecosystem production function, then we can obtain value estimates for ecosystem <u>outputs</u>, such as safe drinking water or safe water for swimming (e.g., CWA designated uses), or ecosystem <u>inputs</u>, such as biophysical characteristics (e.g., pollutant concentrations). What is/are the "policy-relevant" definition(s) of water quality? And are certain valuation methods are to different definitions?

Indexes are alluring but can be tricky. They can help facilitate analysis, and can help communicate complexity, but without a simple theoretical structure, they can also be easily criticized.

How do we reconcile these tensions? Benefit transfer is commonplace, as policy analysts at all levels of government look to the literature for benefits information. How do you (researchers) feel knowing that your published findings could be used to estimate the benefits of a policy beyond the immediate scope of your study (e.g., benefits of agricultural nutrient controls in New England, or Minnesota, or the whole US). For the researchers, how does it feel to know that your research findings may be used in a transfer? Also, how does the geographic scale of your work affect your current research? Could you shift your research into a regional or national scale?
How high are the transaction costs associated with multidisciplinary research?

Summary of the Q&A Discussion Following Session III (Part 1)

Steve Swallow (University of Rhode Island)
Directing his question to Joseph Herriges, Dr. Swallow stated that he noticed most, or perhaps all, of the water quality dimensions were linear. He said he was "just thinking about how a lake ecosystem works—maybe I should talk about nutrients, maybe I should talk about Secchi depths, whatever, but if you can see to the bottom of a lake, that's a lake that doesn't have a lot of nutrients in it." He commented that although that may be aesthetically pleasing, it's not necessarily good for fish and, therefore, might be affecting the "recreation quality." Dr. Swallow continued: "If you raise the Secchi depth up to zero, that means it's eutrophic—everything is growing, and it probably stinks, too." He closed by asking whether Dr. Herriges has "thought about trying to do some non-linearities where there might be a *peak* in the quality from the perspective of what humans are valuing but a difference from the peak in the quality from the perspective of a pristine ecosystem that some of your ecology friends might be focused on."

Joseph Herriges (Iowa State University)
Dr. Herriges explained that he didn't really have time to talk a lot about the specification search part of the study, but a lot of that came from talking with, in this case, the limnologist. He continued, " I showed you a real simple version of the model, but what we're doing in the specification search is looking over a variety of models with both linear and non-linear effects—non-linear effects in terms of Secchi depth and things like that—so we have looked at a whole range of different models and we have found non-linear effects in a number of the variables. In the specification stage, we're searching over both whether to include a variable in the model and also what non-linear form we have." Dr. Herriges stated that "one of the things coming out of this conference is that we need to go back and look at some more non-linearities in the process. The limnologist has been particularly helpful in pointing out which variables might be the ones we focus on because they have *physical* signs that people visiting the lake might see. So, that's why we had the six variables I showed you—those are the ones we focused on initially because the nutrients and so on have particular physical attributes that people can see." He concluded by reiterating that they "have all the other variables in and have looked at a lot of different non-linearities."

Steve Swallow
Dr. Swallow added, "It also might affect the difference you're seeing between different user groups—the people who get in the water versus the people who are on top of the water fishing."

Joseph Herriges
Dr. Herriges replied, "In fact, that's something we *haven't* done, which I think would be useful to do. We have not looked at segmenting the population. The problem there is that different user groups are somewhat endogenous—if you don't like certain types of water quality, you may not be a swimmer *because* you don't like the physical attributes, so there's a bit of a problem modeling what people choose to do."

David Widawsky (U.S. EPA/OPP)
Identifying himself as "both a producer and consumer of ecological benefits analysis," Dr. Widawsky said he wanted to bring the focus back to the subtitle of the workshop: Improving the Science Behind Policy Decisions. Referring to "the talks we heard just now and some of the talks we heard this morning," he stated "policy decisions are often presented as a choice between one set of biophysical properties and another set of biophysical properties. We know that in getting to that different set of biophysical properties, the real decision is not choosing that set of properties but choosing a set of land use decisions and behaviors that are *linked* to the properties and which we can value through the biophysical models that are kind of the *challenge*. As we heard this morning from Nicole and in the keynote address, the challenge is with respect to having an *integrated* model between an ecological assessment model, an ecological valuation model, and an economic model. My question is: To what degree do you gentlemen incorporate biophysical models to describe how all of this gets you to the sub-characterization of value and what challenges were expected getting to an integrated model, and . . . how would you address those challenges?"

Joseph Herriges
Dr. Herriges responded, "The quick answer is: We did not look at that." He continued, "What we're doing in our project, for example, is trying to look at the value that the households place in certain attributes of the lakes, certain water quality levels. I think the question you're addressing is that there's a cost associated with that. You have to understand that if you're really going to evaluate whether to adopt a [program] to try to get these lakes up to a given level of quality, we want to know the benefits of that, and that's really what our project is looking at. But, you also need to know the *costs* of doing that, so you need to be able to model the fate and transport of the various pollutants getting in, how different incentives might cause changes in land use and how those then, in turn, affect the water quality." Reiterating that that's a different issue outside the scope of their study, Dr. Herriges commented, "There is actually a project going on at Iowa State University in the Center for Agricultural and Rural Development trying to do exactly that—trying to pair up our work on getting at the benefits with their own work of trying to model the cost of achieving different levels of water quality through different incentives on land use and set aside and so on.

Kerry Smith (North Carolina State University)
Dr. Smith said, "I should say that I was, as usual, not very clear on what the benefit we measured was. The benefit measured, which I presented at the very end, was just the elimination of the site, in this case Falls Lake, from the choice set. Ray [Palmquist] and Dan [Phaneuf] have done some separate work that, as we develop this index function I'm talking about, would be capable of being used, but it's . . . sort of a reduced form model. What they've done is they've put their variety of different measures based on monitoring

data in the Neuse River watershed of ambient concentrations of different pollutants—nitrogen, phosphorus, and so forth—and then set up a spatial model that takes account of both the timing of the monitoring and the timing of the activities, and in this case it's changes in land cover and land use at points that are upstream of the places where the measurements are taken. Now, in principle, if we had those physical attributes that they are describing in the largely reduced form model, conveyed through our index, then it would be possible to make *somewhat* of a connection. The difficulty is that the closed loop . . . isn't in our model—the closed loop being: suppose we were to take this reduced form model that they've developed that looks at land cover changes and new development (new building permits, new land conversion, and so forth) and it takes that and it links it to total measured phosphorus or nitrogen or something else at a particular point in the river. That gets conveyed through our index up to our housing model, and we say "Okay, no problem, we're just going to put some limits on here—we'll refer to them as brand new versions or something else so it will *simulate* that effect in the reduced form model that they've got, then that will connect to our index, and we'll just value it in the Hedonic model. The problem is that the Hedonic equilibrium is different because it's restricting the nature of the land use that's associated with getting the outcome in the beginning of the model, so the feedback would be passively put in there.

So, the short answer that I should have said was: No, we didn't do that. Those of you who have listened to me so far today know that I *never* give *any* short answer to *any*thing."

Robert LaFrance (Connecticut Department of Environmental Protection)
Mr. LaFrance said, "I've listened to a lot of your academic discussions and I'm wondering: How do you guys relate to local and state officials, both those who are elected and those who are not? Maybe you can give me some sense of your interaction with them, because that's kind of where I'm at and I'm trying to take some of this and bring it back to my job."

Joseph Herriges
Dr. Herriges responded, "I'm not sure how to answer that question. This gets back to this whole issue about interdisciplinary research, too. There are interactions between ecologists and economists, and getting the communication between those two different disciplines *and* communicating with the local and state regulators in the process [is often difficult]. There are costs associated, but there are *huge* benefits as well. In our project the limnologist actually started this interaction by calling and saying that they were doing this extensive study and would like some economic numbers at the end—economists are used to being called in at the very end. Well, what's happened in the process of both of us talking to each other is that the project has evolved into something bigger and broader." He said this expansion of the project involved "bringing in local people and finding out what matters to them in terms of the lake—what changes they're looking at, their interest in local economic impact versus what economists would say in terms of changes in value, etc." Dr. Herriges summarized by saying, "Communication is

extremely important. We've learned a lot by talking to state regulators, and what matters to them is they want to know that people will actually *do* something as a result and that they'll contact their state legislator and there will be *action* coming out of this. So, learning how to communicate with each other is extremely important in this process.

Kerry Smith
Dr. Smith advised Mr. LaFrance to talk to his colleague Dan Phaneuf about that issue. "because he's really had much more experience, not only in the context of developing this model I refer to, but in the context of working with some folks at RTI (RTI International, Inc.) at integrating a watershed model with an economic model for a large local project." He went on to relate this story: "Many years ago I was asked to *pretend* I was an expert witness at a mock trial that took place in New York City—this was about twenty years ago—and the best way of characterizing *me* interacting with public officials was what was *said* after I pretended I was an expert witness and was supposed to be presenting *purely* the results of an economic model. A retired judge who was listening to this looked at the people who had hired me and said, "*Where* did you find *this* person?" That has often been the response I get."

Clay Ogg (U.S. EPA, National Center for Environmental Economics)
Dr. Ogg identified himself as "the Project Officer on the other project that you mentioned where they're looking at the production costs . . . and we did ask them if this cost analysis is directly linked to the lakes that you're looking at, and I think the answer was "No." . . . They did look at one lake though, and for the first lake that they analyzed I think there was a report that indicated you could actually take all the land out of agriculture and that the benefits would be sufficient to pay for that. But, if you're talking about making Iowa lakes look like Okoboji, I think you are talking about something fairly drastic there in terms of taking land out of agriculture. So, it might be useful at least to look at the size of the watershed you're talking about."

Joseph Herriges
Dr. Herriges admitted to not knowing exactly what project Dr. Ogg was speaking about, but said, "They're working on a number of projects, and some of them are very much at a smaller watershed level. The project I'm talking about actually is with the Iowa DNR (Department of Natural Resources), and I think it's a different project than the one you're referring to." He added, "I'm not on the project, so I can't tell you exactly what they're doing, but my understanding is that they're trying to give the state some information about the cost side of achieving some improvements in water quality. I don't know how *broad* it is, but that's the *kind* of thing you have to look at. We're trying to model the benefits, but if we're trying to achieve some of these improvements in water quality, you need to understand the costs and how that works."

END OF SESSION III (Part 1) Q&A